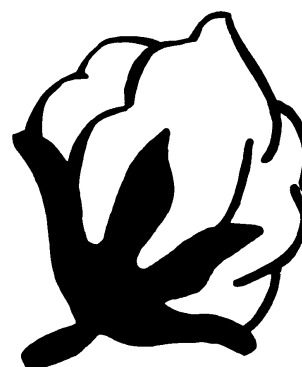


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Technical Report on Research Activities

Improvement of the Marketability of Cotton Produced in Zones Affected by Stickiness



FUNDING AGENCY

Common Fund for Commodities
Stadhouderskade 55
1072 AB Amsterdam
The Netherlands
Tel: ++31 20 575 4949
Fax: ++ 31 20676 0231
Web site: www.common-fund.org

SPONSORING ORGANIZATION

International Cotton Advisory Committee
1629 K street NW, suite 702
Washington , DC 20006
USA
Tel: ++1 202 463 66 60
Fax: ++ 1 202 463 69 50
Web site: www.icac.org

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BODIES PARTICIPATING IN THE PROJECT

The Sudan Cotton Company Limited
P.O. box 1672
KHARTOUM
Sudan
Tel: ++249 11 77 60 53
Fax: ++ 249 11 77 07 03
Email: sccl@sudanmail.net

Cirad-ca
Cotton Technology Laboratory
TA 70/16
34398 Montpellier cedex 05
France
Tel: ++33 467 61 58 00
Fax: ++33 467 61 56 67
Web site: www.cirad.fr

The Agricultural Research Corporation
GEZIRA RESEARCH STATION
COTTON RESEARCH PROGRAM
Wad Medani
Sudan
Tel: ++249 511 43215
Fax: ++249 511 43213
Email: cotarc@sudanmail.net

Institut Français du Textile et de l'Habillement (IFTH)
2 rue de la recherche
59656 Villeneuve d'Ascq cedex
France
Tel: ++33 3 20 19 74 00
Fax: ++ 33 3 20 47 47 16
Web site: www.itf.fr

**FOR ANY TECHNICAL INFORMATION CONCERNING THIS REPORT, PLEASE CONTACT
SUDAN COTTON COMPANY AND/OR CIRAD.**

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Introductory notice: Organization of the report

This report is organized in line with Appraisal Report organization, and as follows:

- First, a global description of the project and its background are given by an extract from the Appraisal Report agreed between the participating bodies. Thus, some information about the cotton situation and its background described here may have changed since due to financial, economical or technical modifications.
- Each of the three components in the project is described through an extract of the Appraisal Report (same comment as above), and then through the different experiments conducted. For each of these experiments, a complete description of the materials and methods used is given, followed by results and their discussion, then by figures, slides or any useful information concerning that particular experiment. At the end of each component, concluding remarks and discussions are given with practical consequences for the organization of the cotton industry.
- Component A: Testing and evaluation of methods for establishing the degree of stickiness in cotton. The reader will want to know about the stickiness measuring devices used in this project: thus, we placed a full description of these in the component A chapter. This was rendered necessary since the reader must be aware of technical information concerning the different measuring devices prior to reading the discussion about their technical ability to characterize stickiness.
- Component B: Development of a threshold for economical processing of sticky cotton.

Component C: Evaluation of the financial viability of the process, training, circulation of project results through presentations, publications and technology transfer.

- At the end of this report, a final project conclusion gives the main results and their implications.
- And finally, an extensive bibliography on the subject is given at the end of this report.

Notice: Five books have been produced by the project. All are available at the Common Fund for Commodities and at Cirad:

- Technical Report N° 17,
- Rapport Technique n° 17,
- Technical Report on Research Activities, available on the Common Fund for Commodities and International Cotton Advisory Committee web sites.
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Executive summary

A bale is declared “sticky” if, during a particular processing step, e.g. spinning, its stickiness level disrupts the spinning process, leading to reduced performance of the spinning machines and/or poorer quality final products. To assess stickiness, a reliable and rapid measurement device is necessary, giving results that are well correlated with the efficiency and the breakage incidence in an industrial-scale spinning mill and the quality of the yarn produced. In this study, we put forward production management methodology and draw up a classification for marketing.

It should be mentioned that a classification requires a measuring tool, proper conditions for that tool, and appropriate cotton production organization. Thus, four steps were initiated to evaluate the feasibility of cotton classification for stickiness:

1. It was first necessary to determine whether any measuring devices were efficient in a classification process. Among the tools evaluated, namely Thermodetector SCT, HPLC and H2SD, H2SD seems to be the most adapted to measure stickiness in these classification conditions, since it is predictive of disruptions spinning processes (OE, RS, combed RS), it is fast and does not show an operator effect. However, the thermodetector SCT can still be used at a laboratory scale.
2. During investigations into the extend and variability of stickiness in Sudanese bales, lots, gin areas, we observed:
 - A wide range of within-bale, within-lot, within-block and within-gin stickiness. Among the production zones, some production areas in Sudan could be considered as non to slightly sticky.
 - The sticky points distribution does not fit a agregative statistical distribution law. However, due to the production conditions in Sudan, no specific law could be deduced from the collected data.
 - It was thus impossible to deduce any possible level of litigation risk between seller and purchaser.
3. A qualitative classification procedure requires a threshold above which a cotton could be considered as sticky. Thus investigations were conducted into the effect of stickiness on productivity and quality in a spinning process. It was deduced that a unique global threshold to separate non-sticky from sticky cottons for all the processing conditions in any spinning mill in the world cannot be found since knowledge, processing technologies, ... are too different. This threshold will have to be negociated for each contract between seller and purchaser Economical incidence should be discussed accordingly.
4. The economical viability of a stickiness classification was studied. This qualitative classification is viable if the stickiness distribution is more centered on low percentage levels of contaminated fibres and if the assumptions we made are proven to be solid.

Two other experiments were designed to ways to reduce the consequences of stickiness.

- Decreasing relative humidity during the spinning process: this improves productivity and quality with a greater improvement in productivity. However, at lower humidities, other problems could appear.
- A binary mix of non-sticky cotton with contaminated cotton: this reduces the level of stickiness for spinning as seen from stickiness measurement on H2SD. The stickiness of a mix was deduced to be the mean of the stickiness levels shown by each constituent weighted by their proportion in the mix, if the sticky cotton has no more than 50 H2SD sticky points.

Combating stickiness requires a global approach where improvements in breeding, agronomy, pest control and technology have to be made in a parallel manner. Classification is one of the tools to combat stickiness. Measurement results through mapping, can help in other ways to reduce stickiness, such as breeding new varieties, developing new ways to manage the crops through integrated pest management programs, managing the seed-cotton flow, etc.

On a long-term basis, the classification tool should be economically viable, and should improve the image of Sudanese cotton.

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Chapter A. Project objective and scope

(Extract from the Appraisal Report)

Stickiness in cotton is mainly caused by sugar-like excretions from two insects (*Aphis gossypii* and *Bemisia tabaci*), and severely disrupts the spinning processes, thereby increasing the cost of spinning and reducing the quality of yarn.

Cotton producers are faced with severe price discounts when selling their cotton if this originates from areas suspected of being contaminated by stickiness. In order for cotton to maintain its competitiveness *vis á vis* synthetic fibers on the world markets, and to at least maintain acceptable profitability levels in production, efforts need to be undertaken to reduce the production and processing costs.

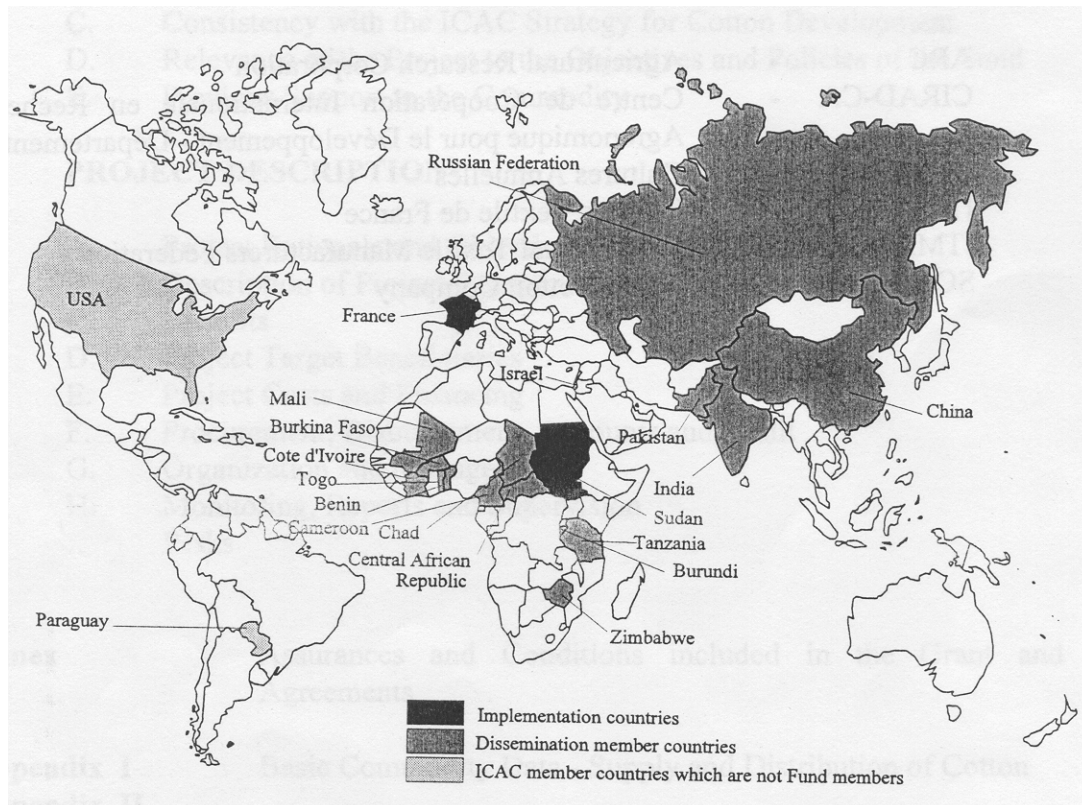
While another Fund-assisted project focused on the development of an integrated pest management system to reduce stickiness in the field, the present project aimed develop reliable methods to separate sticky cotton from non-sticky cotton and determine threshold levels for sticky cotton processing under varying environmental conditions.

These latter trials took place under real production/factory conditions. The methodologies developed and the experience acquired in this project are of benefit to all cotton-producing countries affected by stickiness in one or more of their cotton-production areas. The project comprised the following three components:

- (a) testing and evaluating the process for classifying sticky cotton;
- (b) establishing the process-ability of sticky cotton; and
- (c) evaluating of the financial viability of the processes, training, and dissemination of the process developed by the project.

Map

Location of the Project for Improving the Marketability of the Cotton Produced in Zones Affected by Stickiness¹



Countries experiencing major problems with stickiness in one or more of their cotton-producing areas (source: ITMF - Cotton Contamination Survey, 2000)

¹

The colours, boundaries, denominations, and classifications in this map do not imply, on the part of the Common Fund for Commodities or its Members, any judgement on the legal status of any territory, or any endorsement or acceptance of any boundary. The projections used for maps may distort shape, distance, and direction.

I. INTRODUCTION

A. Project Background

The Standing Committee of the International Cotton Advisory Committee agreed on November 16, 1993, to sponsor a project entitled: " Sticky Cotton: Possible Control Methods from Plant to Yarn". The project focused on the elimination of the causes of stickiness in the field, the development of forecasting methods for areas likely to be affected by stickiness, the development of methods for separating sticky cottons from non-sticky cottons, and on the development of methods to treat stickiness after ginning. The project was submitted to the Fund and reviewed by the Fund's Consultative Committee at its Tenth Meeting in January 1994.

The Committee acknowledged the importance of addressing the problem of stickiness in cotton and its importance in the context of maintaining or improving cotton's competitive position *vis á vis* synthetic products. The Committee was, however, of the opinion that the first two objectives of the project would likely overlap with activities (to be) undertaken in an ongoing project "Integrated Pest Management for Non-Sticky Cotton", which was being implemented in Israel and Egypt, with field activities in Zimbabwe and Ethiopia. The third and fourth objective, however, were considered to be relevant and the proposal was thus adjusted accordingly. Furthermore, a dissemination component was added to the project.

The ICAC prepared a revised project proposal taking into account the observations made by the Committee. The revised proposal, entitled "Improving the Marketability of the Cotton Produced in Zones Affected by Stickiness" was reviewed by the Committee at its Fourteenth Meeting in July 1995. The proposal now focused on two objectives, namely the development of a methodology for systematically measuring stickiness in cotton for the purpose of separating sticky parts from non-sticky parts of the production; and on the development of methods which enable the use of varying degrees of sticky cotton for spinning.

In December 1995, it appeared that the counterpart institute, originally foreseen to play a central role in the project, decided to withdraw due to uncertainties with regard to its changing legal status, which negatively influenced its ability to make longer term commitments in the framework of the present project. Steps were undertaken by both the ICAC and CIRAD in order to identify another collaborating institute which had the technical and institutional capacity to execute the project and which had a confirmed interest in the project as designed. The Sudan Cotton Company was subsequently identified as a suitable new partner in the project. The Consultative Committee, in its Seventeenth Meeting in September 1996, agreed that the implementation and dissemination arrangements foreseen in the project and the commitment of the Sudan Cotton Company to carry out the project work is satisfactory and the Committee therefore agreed to recommend the project for approval by the Executive Board.

B. Overview of Structural Conditions in the Cotton Market

The basis for world cotton demand is the consumption of textile fibers, which in turn depends on the growth of the world economy. In the 1990s world income is expected to rise about 3% per year, with increases in population of about 1.7% and per capita income gains of 1.2%. With this level of income growth, textile fiber consumption should rise 2% per year, with per capita fiber use rising from 7.3 kilograms in 1988 to 7.6 kg in 2000. Cotton is expected to lose its current share of world fiber markets of 46%. Thus cotton demand and production are

likely also to increase at a 2% rate.

Cotton is an annual crop, and thus imbalances between the level of world consumption and world production can be corrected in a year or two, as long as market signals are transmitted to producers. It is expected that world production will be in balance with world consumption in 2000, at a level which is about 30% higher than output in 1993/94.

World cotton prices fluctuate from year to year, primarily in response to changes in world stock levels. There has been no secular increase in cotton prices in the last twenty years, and international prices since 1973/74 have averaged about US 73 cents per pound of lint delivered in Europe. Recent increases in average prices (due to low world stocks of cotton) led to an average price of US 86 cents per pound for 1995/96, but based on current estimates the price is expected to come down.

Cotton remains in intense competition with synthetic fibers. In the last 15 years, cotton has regained share of market lost to synthetics in developed countries, due to market development efforts of cotton-producing countries, competitive prices and shifting tastes of consumers toward natural products. As much of the fiber consumed at the level of the final consumer in developed countries is processed in developing countries, textile mill use of cotton in developing countries has grown at a relatively rapid rate of 4% per year. Cotton share of textile fiber consumption at the consumer level in developing countries, however, has declined in the last 15 years from 66% to around 58%, as higher income levels have permitted consumers in many countries the ability to expand their purchases of synthetics, which are usually more expensive than cotton. Recently, however, cotton has lost share in Japan and many European developed country markets, perhaps due to reduced expenditures for cotton market development by cotton-producing countries. Some further decline is expected in cotton's share of market in developed countries in the period. In developing countries, cotton's share may hold at 58% as gains in cotton consumption take place in higher income developing countries.

The location of cotton production and consumption continues to change. In recent years, there has been increasing concentration of world cotton production, with nearly three-quarters of the total now originating in five countries: China, USA, Uzbekistan, India and Pakistan. It is expected that developed countries will be an increasing source of raw materials for developing countries in the rest of the 2000s. Textile industries in developing countries are expected to expand in both cotton-producing and cotton-importing countries.

The restructuring of the economies and societies in Eastern Europe, the former USSR and South Africa, has led to sharp declines in textile industry activity in these countries and have had a profound impact on cotton markets in the last five years. Textile fiber consumption is expected to recover in many of these markets in the period to 2000s, leading to renewed cotton trade flows. The elimination of the Multi Fibre Arrangement, the basis for import quotas for textile products from developing countries in the USA and Europe, should lead to a more rational geographic location of trade in the next 10-15 years. While agreements under the GATT Uruguay Round are not expected to have any major impact on government policies toward cotton, the environment for reducing trade barriers and subsidies in agriculture is improved and there may be further movement toward freer markets as a follow through to the GATT agreement. This may improve the prospects for cotton.

C. Consistency with the ICAC Strategy for Cotton Development

Stickiness in cotton is considered by the members of the ICAC as one of its key priority areas for study and research. As stickiness in cotton increases both production costs as well as processing costs (thereby also reducing producer prices), the Standing Committee of the ICAC has earlier recommended projects for financing by the Fund in the field of crop protection, while the present project is the highest ranked priority project focusing on the post-harvest side of combating stickiness and damage control activities. Problems associated with the processing of contaminated cotton need to be resolved if cotton is to remain competitive with synthetic fibers while producers still receive remunerative prices. It is recognized by the ICAC members that many developed cotton-producing and -consuming countries have the expertise and the means to address these problems. However, most developing countries do not have the research capacity and the financial means to solve these key problems. It is these countries that are most subject to losses in income and loss of markets if solutions are not found. The ICAC has therefore acknowledged the importance of the exchange of technical information between member countries and close cooperation in the solution of mutual problems. The proposed project is an example of both ICAC's prioritization of activities and the recommended international cooperation.

D. Relevance of the Project to the Objectives and the Policies of the Fund

The project is focusing on measures to reduce losses in the value and quality of cotton, thereby improving its competitiveness. It relates to the development of methods to determine the quality of the cotton produced and the level of process-ability of contaminated cotton. It is expected to result in increased revenues for the producing countries. In line with the Fund's priorities, the project aimed to improve the competitiveness of a natural product and to support research and development related to the processing of natural products for which synthetics and substitutes exists. It will thus strengthen the competitive position of cotton which is facing an increasing competition from synthetic fibers. Furthermore, the focal countries for adoption of the process to be developed are developing countries and the main center of project operation is Sudan, which is a Least Developed Country, heavily dependent on cotton for its economic development. The results of the project will, however, be readily applicable in all other countries facing stickiness problems in the cotton-producing areas. It may thus be considered that the project is in line with the Fund's objectives and policies.

E. Previous Support to the Commodity

The first cotton project approved by the Executive Board for financing by the Fund, was a study in 9 major cotton-producing countries, analyzing the factors behind the differential performances of the cotton sector in those countries. That project, entitled "Study of Cotton Production Prospects for the Nineties" was implemented by the International Bank for Reconstruction and Development (World Bank) and was recently completed. The Fund is presently supporting three ongoing projects sponsored by the ICAC. The three projects are: "Integrated Pest Management for Non-Sticky Cotton" implemented in Israel, Egypt, Ethiopia and Zimbabwe; "Integrated Pest Management of the Boll Weevil in Argentina, Brazil and Paraguay; and "Genome Characterization of White-fly-transmitted Geminiviruses of Cotton and Development of Virus-resistant Plants through Genetic Engineering and Conventional Breeding". Activities for this latter project take place in Pakistan, the UK and the USA. All three projects focus on (applied) research in the field of improving cotton production through the development and introduction of efficient and environmentally acceptable crop protection

methods as well as developing disease/pest-resistant cotton varieties. The total amount of financing already expended and committed in relation to support for cotton projects amounts to SDR 4,938,593, i.e. 16.6% of the total CFC commitments (as at 31 August 1996).

II. PROJECT DESCRIPTION

A. Project Rationale and Objectives

The stickiness problem is very complex as the stickiness of the cotton can be due to *inter alia* the following factors: various contaminants (seed coat fragments, neps, insecticides, oil, etc.); physiological sugars, mainly composed of reducing sugars and nectary secretions; and entomological sugars composed of reducing and non-reducing sugars (honeydew). This latter cause of stickiness/contamination has, for the last few years, been by far the most prevalent form of contamination, and is subject of the research undertaken in the framework of the Fund-supported project in Israel, Egypt, Ethiopia and Zimbabwe, focusing on the reduction of stickiness through effective crop protection methods based on principles of effective integrated pest management. The present project had its focus on the post harvest stage of cotton production.

The occurrence of stickiness is not confined to one or a few countries. This phenomenon, which was of little importance in the beginning of the 1980s seems to have become generalized. A survey undertaken by the International Textile Manufacturers Federation (ITMF) involving 235 companies in 30 countries showed that the stickiness problem is increasing. According to the ITMF report "Cotton Contamination Survey 1995" 20% of the surveyed samples had some level of stickiness, and it continues to be the case in the latest reports. Stickiness has therefore become a worldwide problem. Over the last few years all those involved in the cotton industry, from the producer to the spinner, have become increasingly concerned about the problems related to stickiness and have attempted to find a remedy.

Sticky cottons cause disruptions in the spinning process, fouling the cards, the brush tables, the feed trays and the rotors in open end spinning. Apart from the frequent stoppages which require cleaning of the machines, these honeydew deposits also cause irregularities in the card web, slivers and threads, and lead to the production of poor quality yarn. Once sticky cotton is there, the only solution is to isolate the sticky cotton from non-sticky cotton in order to save heavy economic losses to the growers in areas where the problem exists. Stickiness cannot be detected by observation of the cotton during harvesting or during the ginning process. The stickiness problem is usually detected during spinning. It is a time when nothing can be done except to spin whatever is available. In order to avoid unexpected obstructions of the spinning process, cotton spinners only pay the regular price for ginned cotton when they are certain that the cotton lint is clean and does not contain impurities which affect the spinning process. In case of any doubt they will offer only discounted prices for the 'suspect' cotton. These discounts, ranging from 5-30% of the price, are mostly applied indiscriminately to all cotton originating from an area considered to be affected by stickiness. The development of a method to establish an acceptable level of stickiness in cotton bales and to establish operational thresholds in the processing of sticky cotton will have the dual benefit of protecting growers against unjustified price discounting, and it will enable spinners to spin such a cotton through adjustments in the machinery and spinning conditions or through mixing with non-sticky cotton.

The **central objective** of the project was therefore to increase the return on cotton to producers through the development of reliable methods to establish the level of stickiness in cotton bales, and the establishment (under factory conditions) of operational thresholds for the processing of contaminated, sticky cotton. The establishment of processes to successfully deal with the problems of stickiness in cotton will not only raise prices of cotton in currently affected regions but will increase their quantity of marketable cotton.

B. Description of Project Components

The project comprised the following four components: (a) Testing and evaluation of methods for establishing the degree of stickiness in cotton production; (b) Development of a threshold to enable economical processing of sticky cotton; (c) Evaluation of the financial viability of the process developed under the project, training, dissemination of project results through presentations, publications and technology transfer; and (d) Project coordination, supervision and evaluation.

COMPONENT A

Testing and evaluation of methods for establishing the degree of stickiness in cotton

Chapter B. Component A: Testing and evaluation of methods for establishing the degree of stickiness in cotton

Studies were conducted to test, evaluate and monitor stickiness in cotton in order to separate sticky cotton from non-sticky cotton, and establish the degree of stickiness. The studies were conducted jointly by staff of the Sudan Cotton Company (SCC), the Cotton Program of the Agricultural Research Corporation (ARC) of Sudan; the Cotton Program of CIRAD-CA; and Institut Textile de France (ITF). The SCT-CIRAD thermodetector, developed by the Cotton Technology Laboratory of CIRAD-CA, was used to analyze stickiness. The detection of cotton stickiness using the thermodetection method is based on the deposit of sticky substances onto two aluminum sheets. The cotton sample is heated via a hot plate and releases its humidity. This humidity is absorbed by the honeydew which then sticks to the aluminum sheets during a second, cold-press, phase. The number of sticky points counted is a measure for the level of stickiness of the sample. This thermodetector has been recognized by the International Textile Manufacturers Federation as a reference method to measure stickiness in cotton. Six units were envisaged to be required for the purpose of the project. The units were placed in different locations in SCC and ARC premises in the country, in accordance with the minimum requirements for the necessary measurement capacity. Of these six units only three were financed by the Fund, the three other units were financed by the SCC.

Investigations and measurements focused on the determination of the level of stickiness in cotton from different production areas. Measurement and determination of the degree of stickiness was carried out for different qualities. The situation prior to the project for the cotton classification was:

- seed cotton: classification based on 3 grades for the Acala types and 6 grades plus half grades for the long and extra long staple. The seed cotton was ginned according to grades.
- lint: the bales were classified on the base of one sample per bale by human classers (grade and staple length).
- in addition around 1000 commercial samples per year were evaluated by ARC for length (with fibrograph), strength (with stelometers and pressley), fineness and maturity (with FMT), and stickiness (with minicard). The SCC ordered an HVI (High Volume Instrument) Zellweger Uster to complete the equipment of the ARC cotton research laboratory.

The separation of sticky cotton from non-sticky cotton and the evaluation of the degree of stickiness was undertaken under different ginning methods (roller ginning and saw ginning). For each ginning method approximately 500 bales (a total of 1000 bales were therefore covered) were tested by taking and testing at least 16 samples per bale, for stickiness. Out of the 500 bales tested for each ginning method, 60 bales were selected for tests under component B below. For all bales tested, the relationship between the level of stickiness and the level of infestation by white flies and aphids (which are the main causes of stickiness) were investigated. Variations due to sampling techniques were analyzed and eliminated/minimized for both roller and saw ginned cotton. Once reliable measurements had been obtained, efforts were made to establish the minimum number of readings required to measure the stickiness levels for both roller ginned and saw ginned cotton with an acceptable level of accuracy. Based on the test results bales could be separated into low, medium and high stickiness and offered for sale. Ultimately the project findings will be used to formulate a

strategy for the implementation of a stickiness determination program at the national level, through the testing of 5% each of the representative samples for both saw ginned and roller ginned cotton. About 30,000 bales were tested annually. Corroborative re-tests were undertaken on 2,000 to 3,000 samples by an independent laboratory (of *Cotton Incorporated, Cary, USA*) without charge to the project. Finally attention were given to the implications for cotton export management. Instead of one category of cotton now exported, at least two but possibly more categories of cotton could be offered for sale (free of stickiness, and (in one or more grades) sticky cotton). In this way premiums will be obtained for high quality cotton which hitherto has been subject to generalized pricing and has suffered from unnecessary discounting for stickiness.

In order to achieve the objective of developing, testing and evaluating reliable methods for establishing the level of stickiness in cotton bales, the following outputs had to be produced through the implementation of the described activities.

Output 1.1 Investigate stickiness in cotton coming from different producing areas (Medium Staple, Long and Extra Long Staple areas for both roller and saw ginned cotton).

Activity 1.1.1 Bale samples from various areas famous for producing sticky cotton in Sudan were collected, for roller ginned cotton. Around 500 bales were tested using at least 16 samples per bale (one sample per layer of fiber).

Activity 1.1.2 Bale samples from various areas famous for producing sticky cotton in Sudan were collected, for saw ginned cotton. Around 500 bales were tested using at least 16 samples per bale (one sample per layer of fiber).

Activity 1.1.3 Using the thermodetector, samples were analyzed for stickiness.

Output 1.2 Variation due to sampling techniques will be investigated and eliminated/minimized for both roller and saw ginned cotton.

Activity 1.2.1 Methods will be determined and perfected to take samples and also take measurements of the samples in respect of stickiness of cotton for roller ginned cotton.

Activity 1.2.2 Methods will be determined and perfected to take samples and also take measurements of the samples in respect of stickiness of cotton for saw ginned cotton.

Output 1.3 The minimum number of tests required to know the actual level of stickiness from a given sample or produce will be determined.

Activity 1.3.1 For uniform measurements and better reproducibility of the results, the minimum number of readings required to measure the stickiness level will be established for the roller ginned cotton.

Activity 1.3.2 For uniform measurements and better reproducibility of the results, the minimum number of readings required to measure the stickiness level will be established for the saw ginned cotton.

Output 1.4 Bales with low, medium and high stickiness will be separated and offered for sale accordingly.

Activity 1.4.1 Studies will be undertaken to assess the extent of variability in the level of stickiness from one bale to the other.

Output 1.5 A full package will be decided to determine the actual level of stickiness for all the produce in the country.

Activity 1.5.1 A strategy to monitor and evaluate the stickiness will be finalized.

Activity 1.5.2 The results will be applied on representative sample of the produce for roller ginned cotton (around 5% of the roller ginned cotton bales will be tested).

Activity 1.5.3 The results will be applied on representative sample of the produce for saw ginned cotton (around 5% of the saw ginned cotton bales will be tested).

Activity 1.5.4 The Sudan cotton production is around 600,000 bales per year, the representative sample of the production (5%) will represent around 30,000 bales. Two to three thousand samples will be re-tested by an independent laboratory (Cotton Incorporated, Raleigh, USA) free of charge.

Activity 1.5.5 The bale management for export will be studied as the number of categories for sell will be at least multiplied by two (free of stickiness bales and sticky bales).

The following chapters give answers about the proposed outputs and activities. However, we will discuss the outcomes of this research after relating the scientific studies which were realized.

B.1. Equipments used in this project to measure stickiness

In this research, two measuring devices (Figure B-1) were used to evaluate the stickiness potential of cotton fibers. In complement, some HPLC results have been used to describe more closely what types of sugars are involved in the ‘sticky sugars’

This paragraph is making a review of the utilization of the thermo-mechanical devices which were used in the project and of their conditions of use.

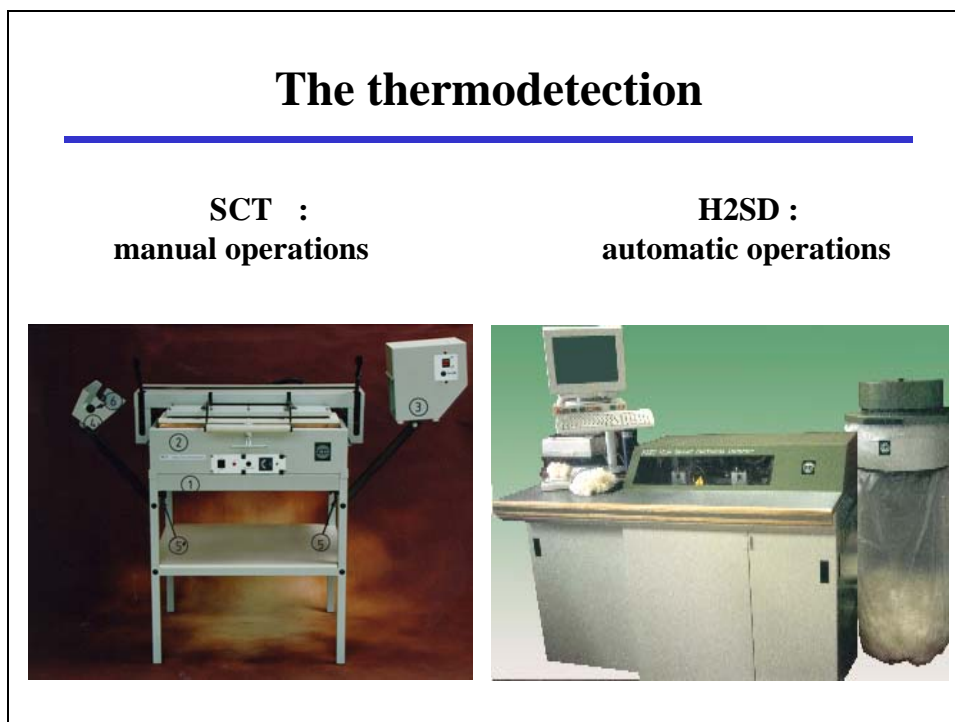


Figure B-1: Two detection devices used to measure stickiness in this CFC / ICAC.

B.1.1. Stickiness Cotton Thermodetector SCT

A standardized procedure was designed to run the SCT. This procedure is the basis of the development of standards at different levels: AFNOR (French organization for standards), CEN (European organization for normalization) and ITMF (International Textile Manufacturer Federation, for which this method is the recommended measuring device for stickiness since 1994).

We give here the procedure that have been used for this research for any individual measurement done.

After a pre-heating phase of the SCT, a aluminum foil is placed on the SCT copper plate (Figure B-2 a). Then, using the specific fiber blender, a mass of 2.5 g of fiber is homogenized and transformed into a web that is placed on the aluminum foil (Figure B-2 b). A second aluminum foil is placed over the cotton web (Figure B-2 c) to form an ensemble. The heating device is placed over the ensemble for a preset time (Figure B-2 d). Then the ambient temperature pressure is placed over the ensemble for another preset time (Figure B-3 a). When the SCT gives the signal, the ensemble is taken from the SCT to be placed in a storage place of about 60 minutes. After this storage time, the upper aluminum foil is removed (Figure B-3 b), and a specific brush is used to remove the cotton web from the lower aluminum foil and the remaining attached fibers on the upper aluminum foil (Figure B-3 c). A counting of apparent sticky points on both foils has to be done Figure B-3 d).

This operation can be repeated as many times as necessary to evaluate the stickiness potential in the fibers with accuracy. The conditioning of the samples and the measurements should be performed in normalized ambient atmosphere (21° C and 65 % relative humidity).

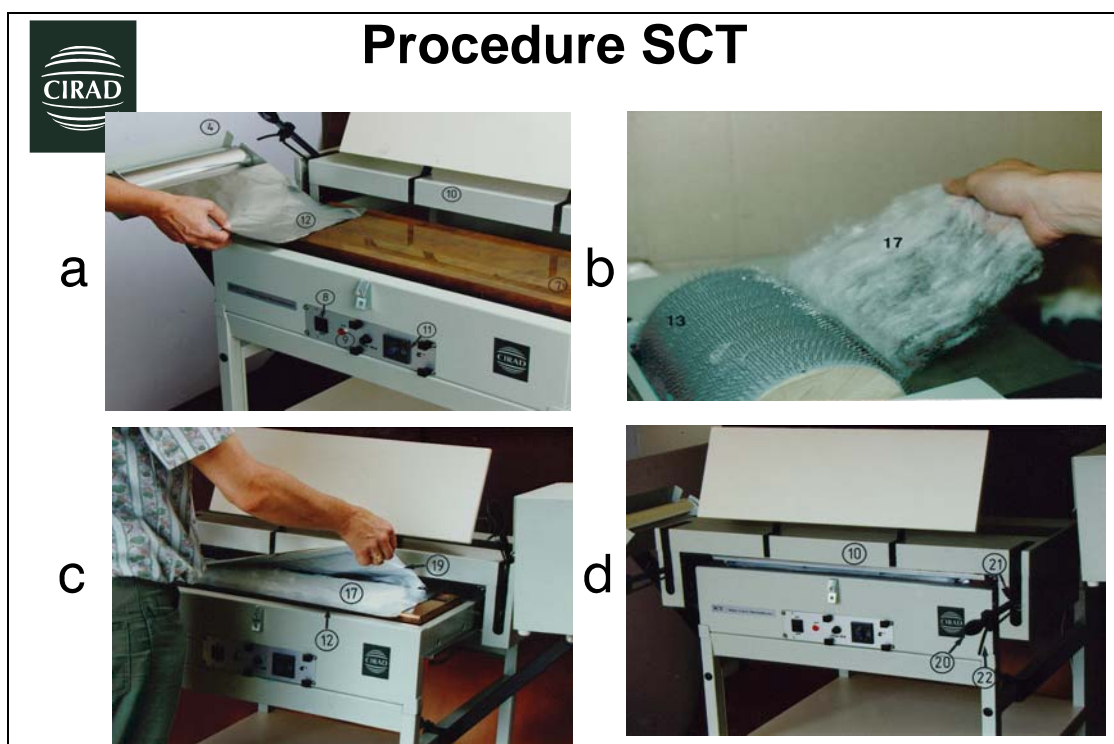


Figure B-2: Procedure SCT

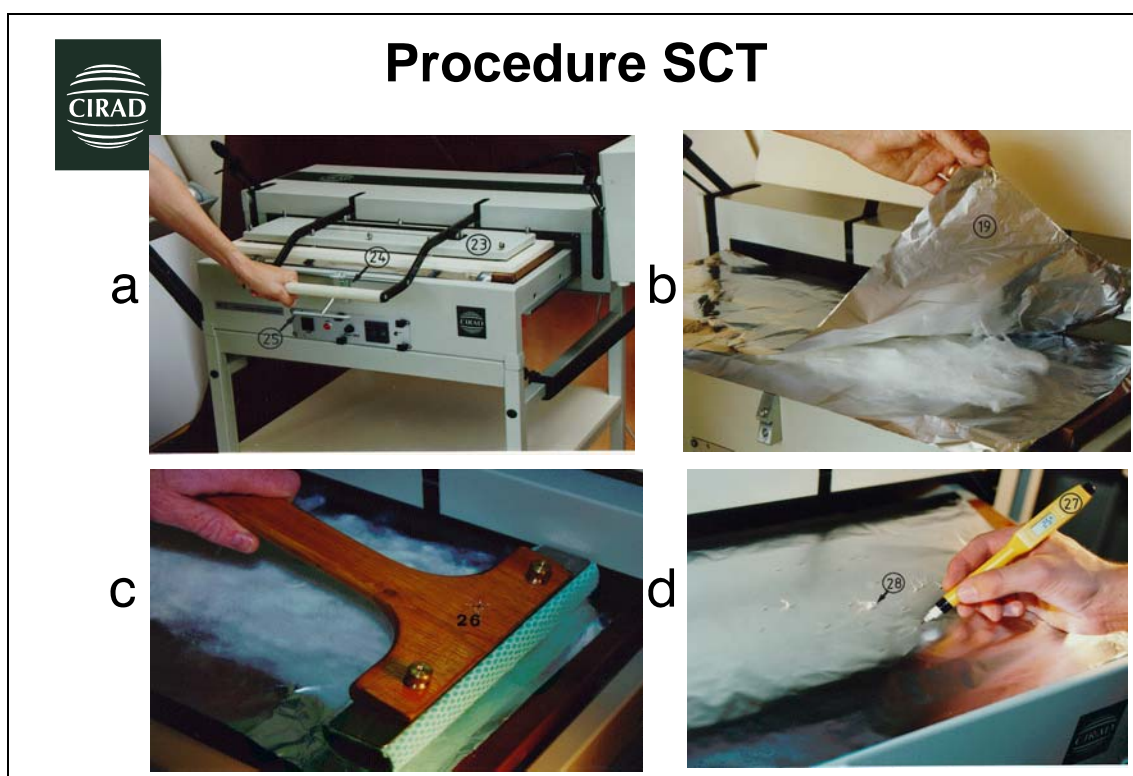


Figure B-3: Procedure SCT (continued)

B.1.2. High Speed Stickiness Detector

As many cottons now show stickiness, the development of a rapid method for the detection of stickiness is more important than ever. The stickiness of cottons during the spinning process has become a selection criterion in the spinning industry. It would therefore be advantageous at the production stage to evaluate the stickiness of each bale. The analytical rate of the H2SD detector is compatible with that of HVI measurement lines and the results it gives correlate well with those obtained on the reference apparatus, the SCT thermodetector. The H2SD is therefore very promising for a bale-by-bale evaluation. The production machine has been improved for intensive use in an industrial environment and modified to provide easy maintenance.

H2SD detection and measurement of stickiness

The analysis is performed at 65% RH and 21°C. The H2SD (Frydrych *et al.*, 1994) is made up of five work stations (Figure B-4):

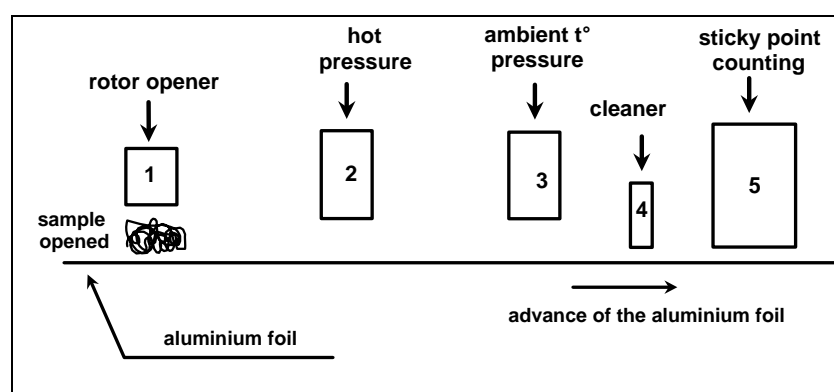


Figure B-4: H2SD 's work stations.

- a sample of cotton (3 to 3.5 grams) is opened using a rotor (Figure B-5 a) to form a mass with a density of about 160 g/m². This is placed on an aluminum foil which passes successively in front of 4 stations.
- Hot pressure (Figure B-5 b) is applied to the sample. The combination of the water in the cotton and the temperature differential between the heat applied and the aluminum, produces a thin layer of wetness on the sheet of aluminum.
- The sticky points in contact with the aluminum foil are fixed in place by pressure exerted at ambient temperature (Figure B-5 c).
- The cotton is then removed (Figure B-5 d; Figure B-6 a)
- and the sticky points are evaluated by an image analyzer (Figure B-6 b and c) which counts the points and determines their size using of a camera and image-processing software. As these stations are independent, four samples can be processed simultaneously. Thus, the machine is able to analyze a sample each 35 seconds.

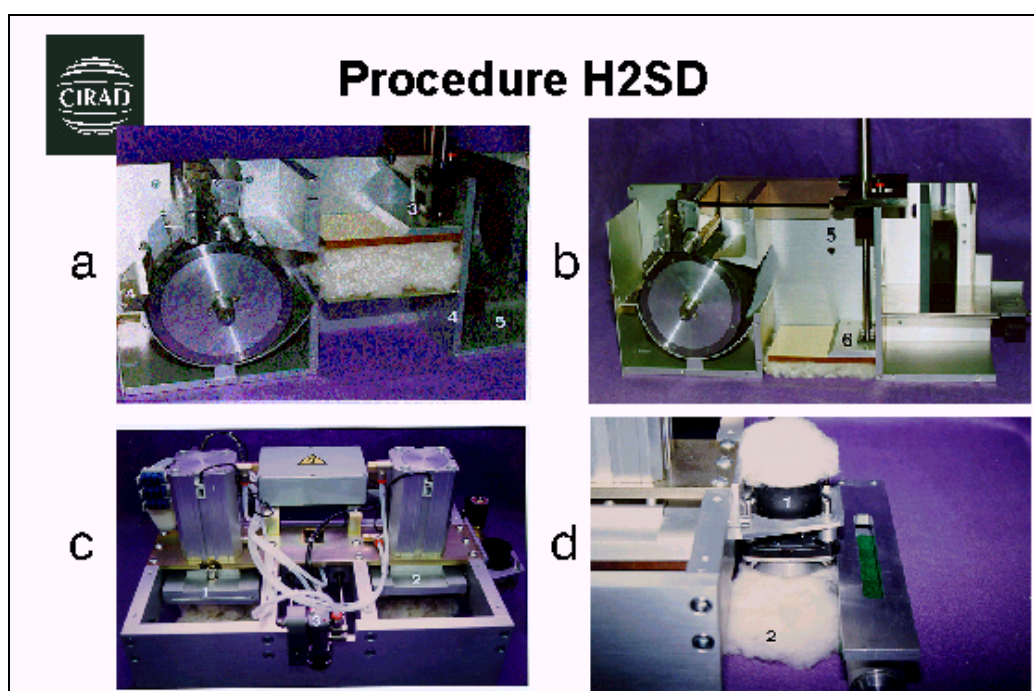


Figure B-5: Processing steps and tools used in the H2SD.

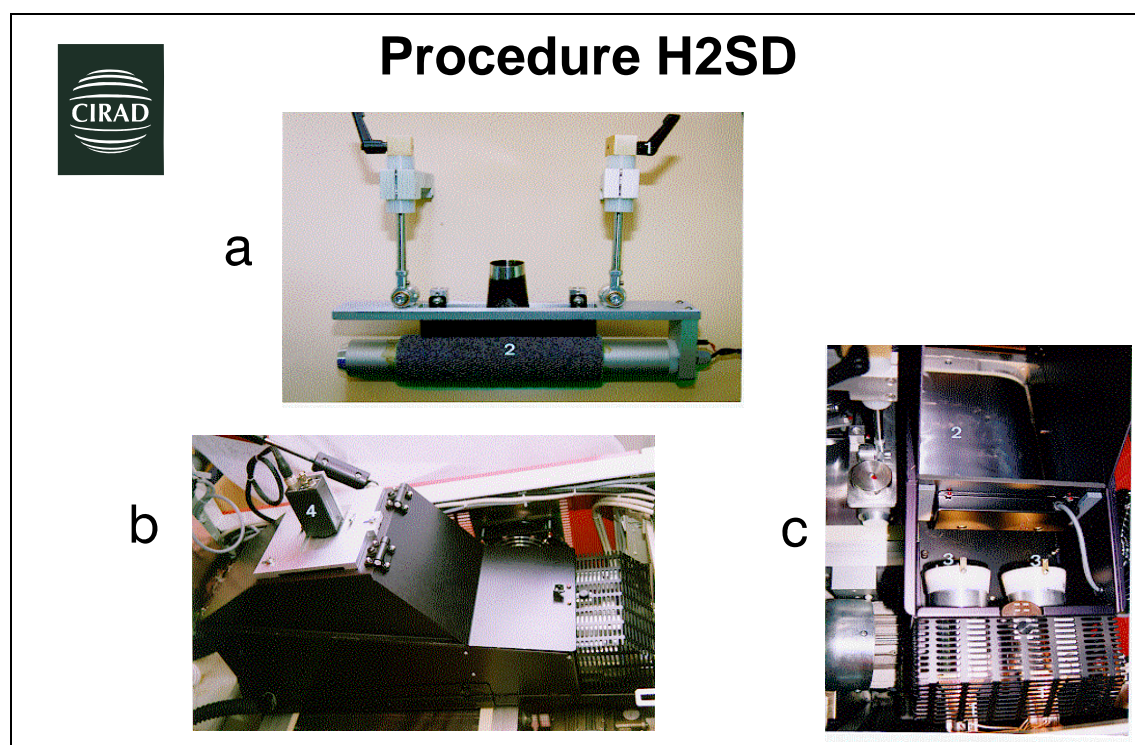


Figure B-6: Other tools used in H2SD.

Information displayed on the screen (Figure B-7) includes a digital image of the sticky points (1), a histogram of sticky-point size (2), the results (3) along with the sample reference name, the total number of sticky points and distribution in three size classes (small, medium and large).

With the use of its tools the H2SD high-speed stickiness detector presents the following advantages:

- human intervention in sample preparation and during stickiness evaluation is reduced to a minimum,
- the measurement is quantitative, giving a honeydew count,
- it is possible to determine the size of the sticky points,
- a result is obtained every 35 seconds.

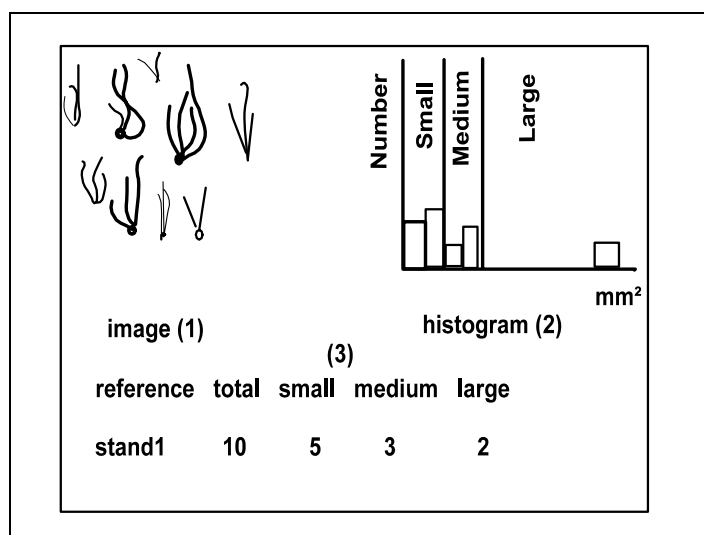


Figure B-7: Information displayed on the screen.

B.1.3. High Performance Liquid Chromatography (HPLC):

International Textile Center in Lubbock runs the following method to determine the individual sugar contents in fiber samples:

- Sticky deposit samples were weighed and placed in plastic bags.
- Twenty ml of 18.2 megohm water were added. A sample of the aqueous solution was taken from the bag with a 10 cm³ syringe on which a 0.2 micron filter (nylon membrane-polypropylene housing) was attached. A 1.5 ml filtered sample was deposited into the 1.5 ml autosampler vial.
- Sugars were separated on the columns (CarboPac PA1 Anion exchange Guard column and two CarboPac PA1 Anion exchange Analytical Columns) in series with a Gradient Eluent system: Eluent 1: 200 mM NaOH and Eluent 2: 500 mM Sodium Acetate and 200 mM NaOH.

This method is used to determine the following sugar contents: Inositol (*I*), Trehalose (*T*), Glucose (*G*), Fructose (*F*), Trehalulose (*W*), Melezitose (*M*) and Sucrose (*S*).

B.1.4. Standardization procedure for sampling

A standard (NF EN 12751 Textiles – Sampling of fibers, yarns and fabrics for testing) is designed to define a proper way of sampling so as to represent a population of textiles.

Different cases are studied depending on fiber presentation (small amount, bales, lots ...). Preparation of the sample prior to testing is also described.

It is stated that bales can be sampled by removing one sample at each end of the bale; however this sampling method can only be used if the variability between bales is higher than that observed between the different layers of any given bale for the considered characteristic to be evaluated. For instance, it is already known that ginning technique affects within-sample variability for some HVI measured characteristics.

This point will be considered in the following section in order to relate this standard to a commercial point of view. Thus, most of the experiments described hereafter were performed by sampling different layers in the bale so as to check the basic hypothesis: within-bale variability is lower than between-bale variability.

B.1.5. Standardization procedure for the SCT measuring device

The following standard is in development under the supervision of the French and European standards committee. Thus, before any use of this SCT method, the latest version of this standard should be consulted in the CEN books. The standard is nevertheless given here to describe as clearly as possible the operating procedure that should be followed for testing. In consequence, the point enumeration listed in the draft standard was modified hereafter to ensure that potential users have a careful look at the original standard as designed by the *ad-hoc* committees.

This procedure was followed during testing conducted at Cirad.

In the classification test on a real-scale level as conducted in Sudan, the work was designed such that some technicians were preparing the specimen using the SCT while others were counting sticky points adherent to aluminum foils.

Textiles - Determination of cotton fibre stickiness using a manual thermodetection device

B.1.5.1. Introduction

The aim of this method is to determine the stickiness potential of cotton fibres by simulating the negative effects of this characteristic during the spinning process. Origins of stickiness are not studied.

Results of this method are not directly related to the determination of sugar content.

This standard consists of the following methods, under the general title "Determination of cotton fibre stickiness":

- EN ("WI 00248318") - Determination of cotton fibre stickiness using a manual thermodetection device
- EN ("WI 00248319") - Determination of cotton fibre stickiness using an automatic thermodetection device
- EN ("WI 00248320") - Determination of cotton fibre stickiness using an automatic mechanical device"

B.1.5.2. Scope

The standard describes a manual thermodetection technique to simulate the tendency of cotton fibres to stick to textile working surfaces.

Test specimens can be raw cotton fibre (fibre sampled e.g. from a bale), or opened fibre, slivers, etc....

B.1.5.3. Normative references

This part of EN WI00248318 incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this part of EN WI00248318 only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies.

EN 20139 Textiles: Standard atmospheres for conditioning and testing.

B.1.5.4. Definition

For the purposes of this part of EN WI00248318, the following definitions apply.

B.1.5.4.1. Stickiness level

Number of sticky points indicating the incidence of cotton fibre stickiness.

B.1.5.4.2. Thermodetection

Action of revealing sticky points through the combined application of heat and pressure.

B.1.5.4.3. Sticky points

Entanglement of fibres or individual fibres that are attached to an aluminium foil as a result of the inherent stickiness of the cotton. Refer to annex for the assessment of what comprises a countable sticky point

B.1.5.4.4. Ensemble

Upper and lower aluminium foils enclosing a fibre sample.

B.1.5.5. Principle

A fibre web, whose surface area and mass are fixed, is placed between two sheets of aluminium foil and pressed at two pressure levels applied successively at different temperature settings to reveal sticky points.

The sticky points are then counted to evaluate the level of stickiness.

B.1.5.6. Apparatus

B.1.5.6.1. Manual thermodetection device

A manual thermodetection device comprises:

NOTE 1 The test method has been developed from practice where values of the major parameters (i.e. applied forces, surface area, temperature and time) have been fixed. Deviation from these values could influence the results.

One rectangular lower (e.g. wooden or other material with similar thermal insulating characteristics) board covered with a copper-plated aluminium platen whose surface area is at least 640 mm x 220 mm;

One rectangular heating plate having dimension of (720 ± 5) mm x (250 ± 5) mm that ensures a force of (780 ± 50) N which should be evenly distributed on the ensemble. Temperature is set at $84^{\circ}\text{C} \pm 4^{\circ}\text{C}$ through an electronic regulator.

One rectangular upper (e.g. wooden) board, whose having dimension of (640 ± 5) mm x (220 ± 5) mm, that ensures a force of (590 ± 50) N can be evenly distributed on the preparation.

The devices to apply forces and temperatures can be securely located to ensure even pressure distribution on to the specimen.

B.1.5.6.2. Aluminium foil

A sheet of aluminium, whose thickness is (15 ± 5) microns - or (40.5 ± 13.5) g/m² - having at least one matt surface exhibiting no traces of oxidation of width at least 250 mm.

B.1.5.7. Electromechanical opener and accessories

Comprising:

- a) A rotating cylinder covered by a flexible card clothing: wires with a density of 8 teeth per cm^2 (also expressed generally as "50 teeth per square inch"), having a length of 11 mm with angles of $12^\circ/30^\circ$ (figure 1) and diameter of 0.5 mm, a feeding plate and feeding cylinder.

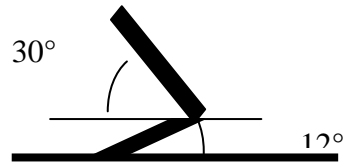


Figure 1

- b) The rotating cylinder width and diameter are calculated to obtain a fibre web whose dimensions are (540 ± 20) mm x (160 ± 20) mm.
- c) The feeding cylinder diameter is (35 ± 1) mm.
- d) Revolution speed of rotating cylinder is $(150 \pm 25) \text{ min}^{-1}$.
- e) Gear ratio between rotating cylinder and feeding cylinder is of 40/1 to 41/1.

NOTE 2 A rotating cylinder (without card clothing) with a diameter of (155 ± 1) mm and its width is (200 ± 1) mm has been found suitable.

The feeding table width is (164 ± 1) mm.

B.1.5.8. Accessories

- a needle to extract the fibre web / length at least 200 mm,
- a brush to clean the flexible card wire clothing of the electromechanical opener.

B.1.5.8.1. Cleaner

The cleaner width is (230 ± 10) mm . The cleaner mass is (400 ± 20) g. The cleaner is covered with a non-woven fabric impregnated with a mineral oil (about 10%) to cause the removal of non sticky fibres

Shape and geometry of the cleaner has to be chosen in order to apply any force on the cleaner and any pressure during the cleaning (see § 8.6).

B.1.5.8.2. Light source

White light source, whose nominal power is (110 ± 10) W, with 30° geometry, so that oblique light illuminates all of the surface area of the aluminium foil.

B.1.5.8.3. Fan

A means of blowing a current of air across the surface of the aluminium foil to vibrate adhering fibres.

B.1.5.9. Atmosphere for conditioning and testing

The atmosphere for conditioning and testing defined in standard EN 20139 shall be used.

B.1.5.10. Preparation of test specimens

Cotton fibre samples are conditioned for at least 24 hours in the atmosphere defined in 6.

Pick the laboratory sample randomly in several places.

Fibre test specimen weight is (2.5 ± 0.05) g.

B.1.5.10.1. Electromechanical opener

- Clean the card wire cloth using the brush.
- Open and mix a conditioned fibre sample by hand, to obtain an homogenous pad. Place it on the width of the feeding plate of the electromechanical opener.
- Run the opener to create an homogeneous cotton fibre web on the rotating cylinder.
- When the rotating cylinder stops, use the needle to extract the fibre web. Take one end of the web with one hand (or a folded paper) and remove it carefully from the card wire clothing by pulling it while manually turning the rotating cylinder with the handle, avoiding deformation of the fibre web.
- The web should be directly laid down on the aluminium foil.
- The web specimen obtained should be (540 ± 20) mm x (160 ± 20) mm.

In the case of an alternative specimen preparation method (for instance, sampling from a card web), the specimen should have a mass of (29.5 ± 4) g/m².

B.1.5.11. Procedure

B.1.5.11.1. Thermodetector set up

Heat the hot plate to obtain a temperature of $84\text{ C}^\circ \pm 4^\circ\text{C}$ on its entire surface. During the heating, place the hot plate over the copper plated aluminium plate but do not secure.

B.1.5.11.2. Specimen positioning on the copper plated aluminium platen

- Cut a piece of aluminium foil to appropriate length to cover the copper plated aluminium plate. Place it on the plate presenting its matt face upwards.
- Place the fibre web specimen on the aluminium foil.
- Cover the specimen with a second aluminium foil of appropriate length, having its matt face against the specimen (avoid finger tips on the aluminium foils matt faces).

B.1.5.11.3. Heating phase of the test

Position the heating plate over the ensemble and locate securely. Apply pressure of (780 ± 50) N and maintain temperature of $84^\circ\text{C} \pm 4^\circ\text{C}$. Maintain this phase for (12 ± 2) s.

B.1.5.11.4. Ambient phase of the test

- Unfasten the heating plate and remove from the ensemble.
- Immediately apply and secure the upper (e.g. wooden) board and apply a pressure of (590 ± 50) N to the ensemble for (120 ± 10) s.

B.1.5.11.5. Removal of the ensemble

- Unfasten the upper (e.g. wooden) board.
- Remove the ensemble and allow to stand for at least (60 ± 5) min.

B.1.5.11.6. Counting the sticky points

- Carefully remove the upper aluminium foil. Lay it down with the matt face upwards.
- Without exerting any pressure, apply the cleaner to the lower aluminium foil along its length first in one direction then the other.
- Illuminate the lower aluminium foil with the oblique light source. Light may be applied from any side. Use the fan to vibrate the adhering fibres. Count and record the sticky points.
- Repeat the process for the upper aluminium foil, but apply the cleaner in one direction only.

It is recommended that the sticky points which have already been counted are marked with a suitable pen. This avoids counting some points twice and forgetting others and allows subsequent verification without the application of the light source or fan.

B.1.5.11.7. Repetition

Repeat the entire procedure from 9.1 to 9.6 with 2 additional test specimens from the same sample.

B.1.5.11.8. Calculation and expression of results

- Add together the number of sticky points recorded from the upper and lower aluminium foils for each test specimen.
- Average the results of the 3 test specimens.

B.1.5.12. Test report

The report shall contain the following information:

B.1.5.12.1. General information

- Reference to this European standard.
- Identification of the test sample and sampling procedure if required.
- Any deviation from the given procedure.

B.1.5.12.2. Test results

- Total number of sticky points for each test specimen
- The average result of the 3 test specimens.

B.1.5.13. ANNEX A (informative)

B.1.5.13.1. Standardization of the results: Calibration

The technician plays an important role in the precision of the results, with an impact on the quality of the ensemble, the cleaning and the counting.

For research purposes, with trained technicians, variations in sticky point counts have been found to be insignificant.

Since manual counting can be significantly influenced by the operator, some precautions have to be taken to limit this effect. The quality of the measurements made by each operator should be controlled periodically using anonymous samples, whose stickiness degree is not known in advance by the operator.

In addition, if many samples are to be analysed by several operators, it is recommended to randomize the order of analysis of the individual specimens issued from one sample. This will avoid one operator reproducing the same unconscious counting errors in the 3 specimens of a given sample.

When many technicians operate, it is recommended to split the measurements among them.

B.1.5.13.2. Statistical analysis

For research purposes, statistical processing of the data is generally necessary to determine differences between two treatments. The statistical analysis of the number of sticky points shows that their distribution is not Normal / Gaussian and is more like a Poisson or a negative binomial distribution. Thus, variance increases with the number of sticky points, and its stabilisation is necessary prior to any statistical analysis with linear model as regression or one way analysis of variance. 'Square root' transformation of the number of sticky points can be used for one-way analysis of variance. Experiments with 2 factors or more should be analysed using a log-linear model, and require a statistician.

B.1.5.13.3. Repeatability and reproducibility

This test method is awaited internationally since thermodetection devices have been distributed throughout the world.

On the basis of the standardised test method, inter-laboratory trials could be organized to determinate method repeatability and reproducibility.

B.1.6. Standardization procedure for the H2SD measuring device

The following standard is in development under the supervision of the French and European standards committee. Thus, before any use of this H2SD method, the latest version of this standard should be consulted in the CEN books. The standard is nevertheless given here to describe as clearly as possible the operating procedure that should be followed for testing. This procedure was followed during testing conducted at Cirad.

Determination of cotton fiber stickiness — Method using an automatic thermodetection plate device

B.1.6.1. Introduction

The aim of this method is to determine the stickiness potential of cotton fibers by simulating the negative effects of this characteristic during the spinning process. Origins of stickiness are not studied.

Results of this method are not directly related to the determination of sugar content.

This standard consists of the following methods, under the general title "Determination of cotton fiber stickiness":

EN ("WI 00248318") - Part 1: Method using a manual thermodetection device

EN ("WI 00248319") - Part 2: Method using an automatic thermodetection plate device

EN ("WI 00248320") - Part 3: Method using an automatic rotating drum device"

B.1.6.2. Scope

The standard describes an automatic technique to simulate the tendency of cotton fibers to stick to textile working surfaces.

Test specimens can be raw cotton fiber (fiber sampled e.g. from a bale), or opened fiber, slivers, etc....

B.1.6.3. Normative references

This standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies.

EN 20139:1992, Textiles - Standard atmospheres for conditioning and testing.

B.1.6.4. Definitions

For the purposes of this standard, the following terms and definitions apply.

B.1.6.4.1. Stickiness level

Number of sticky points indicating the incidence of cotton fibre stickiness.

B.1.6.4.2. Thermodetection

Action of revealing sticky points through the combined application of heat and pressure.

B.1.6.4.3. Sticky points

Entanglement of fibres or individual fibres that are attached to a working surface as a result of the inherent stickiness of the cotton.

B.1.6.4.4. Pad

Thick fiber web , condensed after an opening process.

B.1.6.4.5. Remover: A device to take the non sticking fibres away from the counting surface.
Principle

A fiber sample is processed through an opener to obtain a pad. This pad is pressed onto aluminum foil at two pressure levels applied successively at different temperature settings to reveal sticky points. After removing the pad and loose fibers from the aluminum foil, the sticky points are then automatically counted by image analysis to evaluate the degree of stickiness. All the operations and the analysis of the results are computer controlled.

B.1.6.5. Apparatus

B.1.6.5.1. Automatic system

The sequence of the operations in the automatic system is as follows:

- preparation of the pad
- application of heat and pressure on the pad
- application of pressure at ambient temperature on the pad
- removal of the pad, the non sticking and loose fibers from the aluminum foil
- image analysis for counting the sticky points

B.1.6.5.2. Preparation of the pad

The fiber sample has a weight of (3.25 ± 0.25) g and a surface area of (222 ± 30) cm². The sample is opened using a mechanical rotor-type opener to obtain a very homogeneous fiber-mounting interface and to allow all types of cotton (saw or roller ginning) to be processed. When opened using a rotor opener, the surface in contact with the mounting is comparable to that seen with saw ginned cottons.

B.1.6.5.3. Application of heat and pressure

The sample is then placed on a strip of aluminum foil originating from a roll. The aluminum foil is rolled along a conveyor belt which transfers the sample in front of each station. The aluminum strip is rolled up at the other end of the machine. Pressure is then applied to the sample for (25 ± 2) s while the heating element is in contact with the cotton. The heating element exerts a force of (1700 ± 100) N. Its surface area is (192 ± 1) cm².

B.1.6.5.4. Application of pressure at ambient temperature

Another pressure is then applied for (25 ± 2) s at ambient temperature immediately after the hot pressure phase. This fixes the sticky points to the aluminum foil. The same amount of pressure is applied as during the hot-pressure phase. Its surface area is (192 ± 1) cm².

B.1.6.5.5. Removal of the pad

The surface of the aluminum foil is cleaned by a cylinder covered with a technical fabric (specific carpet), after the fibers of the pad have been removed by suction.

B.1.6.5.6. Image analysis

The sticky points are counted by a video camera as it scans the sheet. The image is then analyzed by computer. The software used calculates the number of sticky points and produces a histogram of sticky point areas.

NOTE . As each station processes independently, it is therefore possible to process up to 5 test specimens simultaneously, which means that a result is obtained almost every 30 seconds.

B.1.6.5.7. Aluminum foil

A sheet of aluminium, whose thickness is (15 ± 5) microns - or (40.5 ± 13.5) g/m² - having at least one bright surface exhibiting no traces of oxidation and a width of at least 250 mm.

B.1.6.6. Atmosphere for conditioning and testing

The atmosphere for conditioning and testing defined in standard EN 20139 shall be used.

B.1.6.7. Preparation of test specimens

Condition the cotton fiber sample (laboratory sample) for at least 24 hours under standard conditions.

NOTE: When processing cotton fiber sample with high humidity, sample pre-drying could be required.

Prepare three test specimens picking fiber tufts randomly from the laboratory sample.

The weight of each fiber test specimen is (3.25 ± 0.25) g.

B.1.6.8. Procedure

B.1.6.8.1. Automatic device set-up

Follow supplier recommendations: cleaning, stabilization of the instrument, calibration operation, use of the software...

B.1.6.8.2. Equipment operation

Introduce a fiber test specimen into the feeding zone of the opener and run the test.

The automatic device runs the test specimen through all the operations described above in paragraph 5.1.

Sticky points are counted by image analysis.

Repeat the procedure with the 2 other test specimens.

B.1.6.9. Calculation and expression of the results

Express the total number of sticky points calculating the arithmetic mean of the results of the three test specimens.

NOTE: The sticky points could be classified into 3 categories according to their size: small, medium and large.

B.1.6.10. Test report

The report shall contain the following information:

B.1.6.10.1. General information

- Reference to this European standard;
- Identification of the test sample, and sampling procedure if required;
- Any deviation from the given procedure.

B.1.6.10.2. Test results

- Number of sticky points for each specimen;
- The mean value of the 3 tests.

B.1.6.11. Annex (normative): Checking

Use 3 cotton standards.

Results should be within the confidence interval of the reference data given by the supplier.

If not, go to Automatic device set-up and follow supplier recommendations.

B.1.6.12. Annex B (informative): Statistical information

B.1.6.12.1. Statistical analysis

For research purposes, statistical processing data transformations are generally necessary to determine differences between two statistical treatments. The statistical analysis of the number of sticky points shows that their distribution is not Normal / Gaussian and is more like a Poisson or a negative binomial distribution. Thus, variance increases with the number of sticky points, and its stabilization is necessary prior to any statistical analysis with linear model as regression or one-way analysis of variance. ‘Square root’ transformation of the number of sticky points can be used for one-way analysis of variance. Experiments with two factors or more should be analyzed using a log-linear model, and require a statistician.

B.1.6.12.2. Repeatability and reproducibility

This test method is awaited internationally since thermodetection devices have been distributed throughout the world.

Based on the standardized test method, inter-laboratory trials could be organized to determinate method repeatability and reproducibility.

B.2. Discussion – Conclusion

Through this in-depth description of the measuring methods and operating procedures, we can already imagine the difficulties involved in maintaining such equipment in good shape.

It is of obvious to maintain the equipment so that no drift occurs due to machine settings.

A standard is simply a means whereby different parties agree to measure a given parameter in the same way. Thus, even if the procedures have been standardized, anyone can use any method the way he wishes. However, it is always better to use a measuring method according to a well-known standard, especially when results will be compared to other laboratory information.

The sections given above are extracts from the future European Standards that are on the way to be validated according to the rules of this committee. We wish thank M. Laurent Houillon, Convenor on Stickiness Working Group within the TC 248, for letting us present these extracts of the standards as they are at the present time.

A lot still remains to be done in the standardization procedure. Indeed, in the same way as for other devices, stickiness measuring devices will require internal and external calibration. At that point, the above standards give some information about the internal calibration: this mainly concerns equipment settings.

Concerning external calibration, we will need reference samples with very precisely determined stickiness values to check whether the measuring devices installed in different locations are able to ‘read’ the same stickiness level. This measurement reproducibility for well-known reference bales is directly dependent on how well the cotton is mixed and/or how well the sampling procedure is performed prior to testing.

A classification procedure would require the same within-bale cotton homogeneity for the different characteristics. However, it is necessary to know the actual level of within-bale stickiness variability in order to prepare the classification procedure, and if necessary, to adjust the production parameters, e.g. the seed-cotton collection.

In the next chapter, we will attempt to evaluate the variability of within-bale stickiness. With this information, it should be possible to determine:

- the number of samples to be taken per bale;
- the number of measurements per sample, this information is required to try to deduce the breadth of the confidence intervals, and to give stickiness readings within these given restricted confidence intervals;
- the risk that a reading made during classification is different from that determined in the purchaser’s laboratory. This evaluation has a direct link with the number of possible complaints between a seller and a pruchaser.

B.3. Experiment on 5% of Sudanese production using the SCT

B.3.1. Objective

An experiment was performed to determine the stickiness level of Sudanese cotton based on a 5% sample of the production.

B.3.2. Introduction

Two complete crops were sampled at a 5% level in the most important production zones in Sudan. In the normal organization in Sudan, seed cotton bags come to the gin after a visual classification for color, trash and length and a classification into 3 grades. Each grade is ginned separately. Bags of the same visual grade are mixed without taking account of the production origin (block). After proper conditioning of the seed-cotton, the bags are emptied behind the gin stands, and seed-cotton is manually fed to the roller ginning machines. The lint is collected and mixed on a conveyor belt which drives the lint to the bale press. One group of 100 bales (or 300 bales in some factories) is called a lot.

In this experiment, seed cotton from different production blocks was ginned separately (i.e. the opposite from that described above) for the following reasons. The objective of the project was to separate the sticky part from the non-sticky part of the production. If we consider that a block is quite homogeneous and that some blocks are free of stickiness, mixing different blocks solely on the basis of the seed-cotton grade (as is done under normal conditions) will certainly result in mixing sticky with non-sticky cottons. Mixing bags of a same block should be acceptable since we assumed that cotton in the block production was homogeneous, but nonetheless depends on within-block stickiness variability.

B.3.3. Material and method

On that cropping year, this experiment represented the collection and analysis of 15885 bales with 2 samples per bale. Five bales uniformly selected (bales 20, 40, 60, 80, 100 ...) from each lot of 100 bales were sampled (2 samples per bale). One SCT measurement was performed on each of the 31770 samples.

This experiment corresponds to true 5% sampling, a showed considerable variation factors since it represents the routine way of working in Sudan. The sampling covered 5 production zones where 1 or 2 variety groups were grown. Each zone could contain both roller and saw gin factories to process the seed cotton. Seed cotton can be produced by 2 varieties. For these reasons, the analysis of such an experiment is somewhat difficult in a standard statistic model. We will then give a data description before giving some variance analysis conclusions assuming a given model.

B.3.4. Results and discussion

The data analysis was performed on the averages of the 2 measurements made for every bale. Figure B-8 represents the quantile boxes for the 3 factors variety * factory * ginning methods (roller or saw) combined into. This is the best way to summarize the important information extracted from the experiment. It was assumed that the observed data is close to a Poisson distribution. The data was square root transformed.

First, we can see that the stickiness means for the 7 combinations were different, and that the stickiness ranges were very different one from another. A marked effect may be exerted by one of the three factors merged in the codification “Variety / Factory / Ginning type” that is kept encoded for commercial purpose.

Then, in view of the analysis of variance (factory * variety * gin * lot * bale), the most important effect (highly significant for each gin) in this experiment was found to be the lot effect as shown in Figure B-9 to Figure B-15. For each combination, the average results are given for each lot sampled.

In these experimental conditions, we demonstrate that the variability of within-lot stickiness is low (non significant effect of the bale within the lot). This means that the operating conditions, prior to and during ginning, enable the production of homogeneous lots having defined stickiness levels. This is illustrated by Figure B-16 where the average level of stickiness is given for the selected bales within the lots (stickiness averages per bale position in the lots).

When comparing the data from two different crops where the same sampling procedure was applied, we observe an interesting decrease in stickiness within Sudanese production. This trend decreased average stickiness from 40 sticky points during the 1997/98 season down to 20 SCT sticky points during the 1998/99 crop season (Figure B-17).

B.3.5. Conclusion

In this experiment, production organization was altered compared to normal routine practices, so that seed-cotton bags were not mixed all together with bags from different production zones (blocks). In these production conditions, we expected to see a loss of homogeneity between lots and an increase in within-lot homogeneity of results.

The data analysis confirmed our expectations through a highly significant effect on the lot (differences between lots are notable) while the 'bale' effect within the lot was not significant (no stickiness difference between the bales of a single lot).

These conclusions could lead to a modification in Sudanese production organization, to produce cotton lots with a specific stickiness level, as assessed by a classification process.

This organization would allow non-sticky cottons to be removed from the production for sale at the international market price. Later in this document, we will review the conditions to be respected in order to ensure "certification" of the stickiness level determination for each lot and consideration of the litigation risk between a seller and a purchaser for these raw materials.

The information collected in such a production organization (no grouping together of seed cottons from different production zones + classification process) could also be used to improve our knowledge about the true production zones. When seed cotton from different zones is mixed, this results in "bulk" seed-cotton from a large production zone area, without locating exactly the "sticky part". Thus it becomes difficult to determine the source of the problem and verifying measures are therefore impossible. By contrast, the ginning of seed-cotton from given production blocks renders it easier to find which zones furnish 'sticky cotton', where corrective measures should be applied.

In short, specific production methods could result in more homogeneous lots (at least for stickiness). This organization should also integrate a classification process to assess the stickiness of the bales, and these results could also be used to link stickiness data to pest infestation on limited production zones in order to draw conclusions concerning crop management (in general terms).

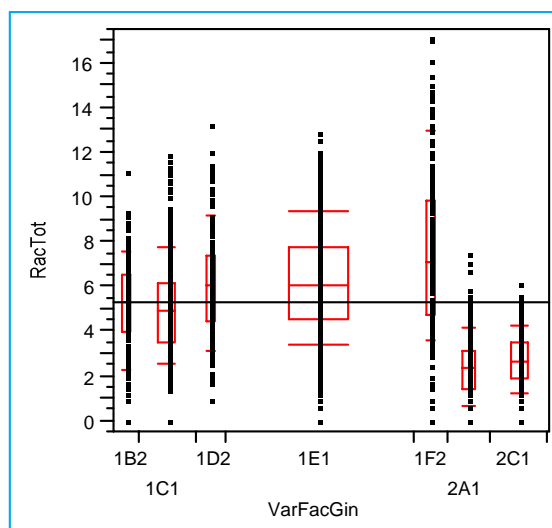


Figure B-8: Distribution of SCT-measured stickiness for different Variety / Factory / Type of ginning combinations.

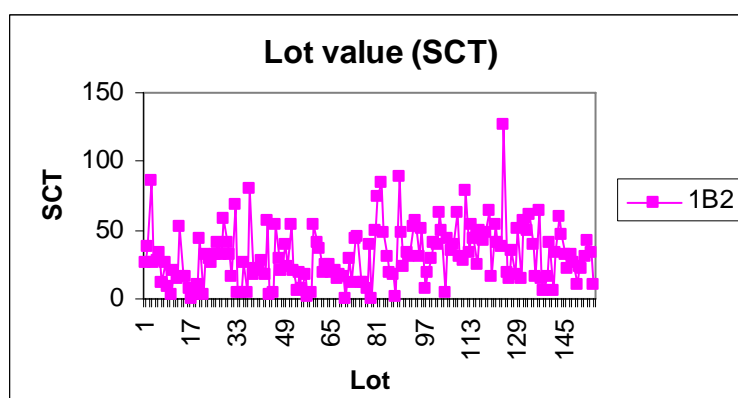


Figure B-9: SCT results on lots from one Variety / Factory / Type of ginning combination.

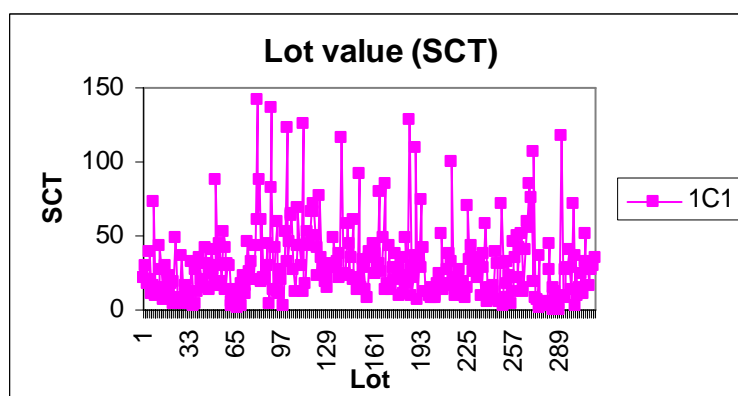


Figure B-10: SCT results on lots from one Variety / Factory / Type of ginning combination.

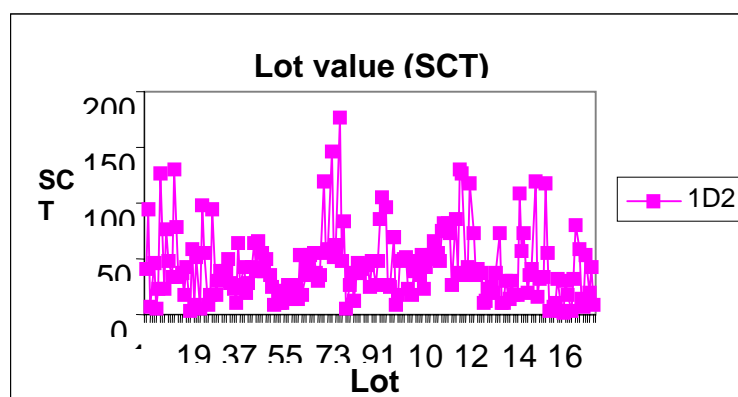


Figure B-11: SCT results on lots from one Variety / Factory / Type of ginning combination.

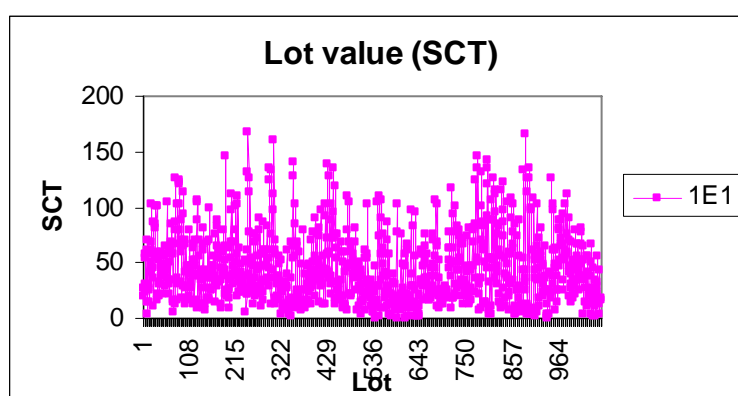


Figure B-12: SCT results on lots from one Variety / Factory / Type of ginning combination.

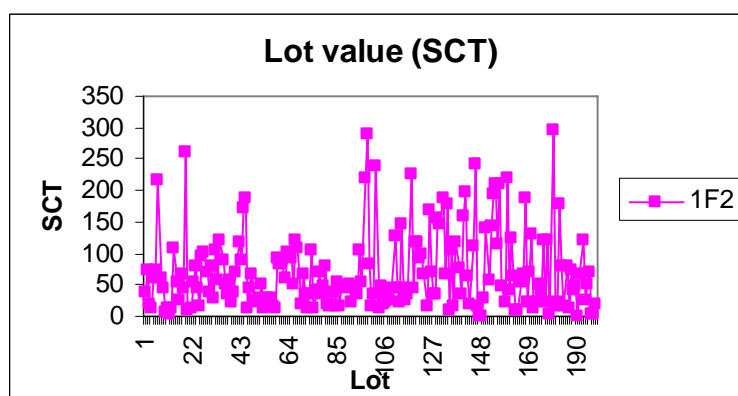


Figure B-13: SCT results on lots from one Variety / Factory / Type of ginning combination.

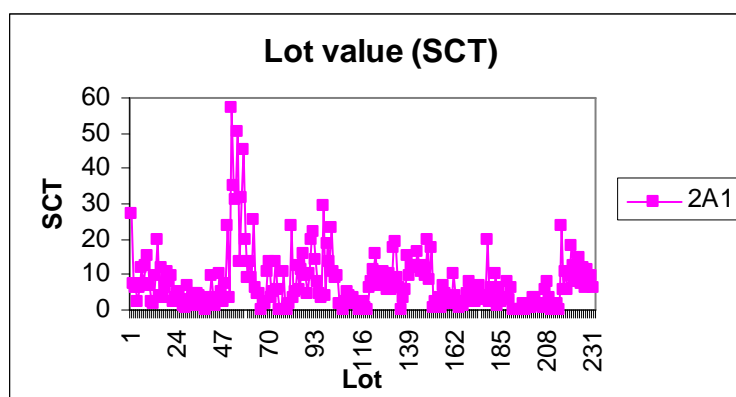


Figure B-14: SCT results on lots from one Variety / Factory / Type of ginning combination.

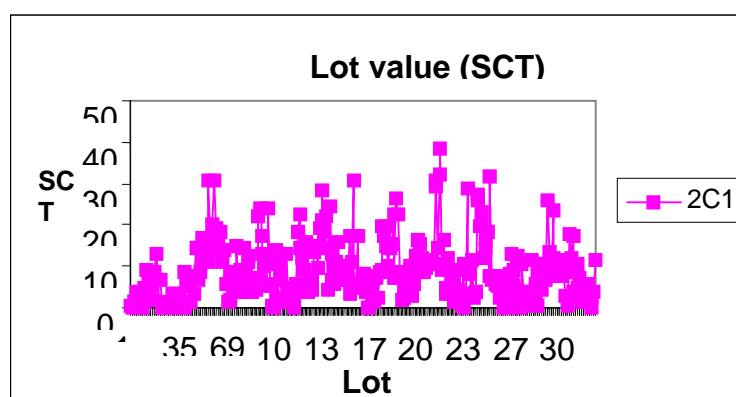


Figure B-15: SCT results on lots from one Variety / Factory / Type of ginning combination.

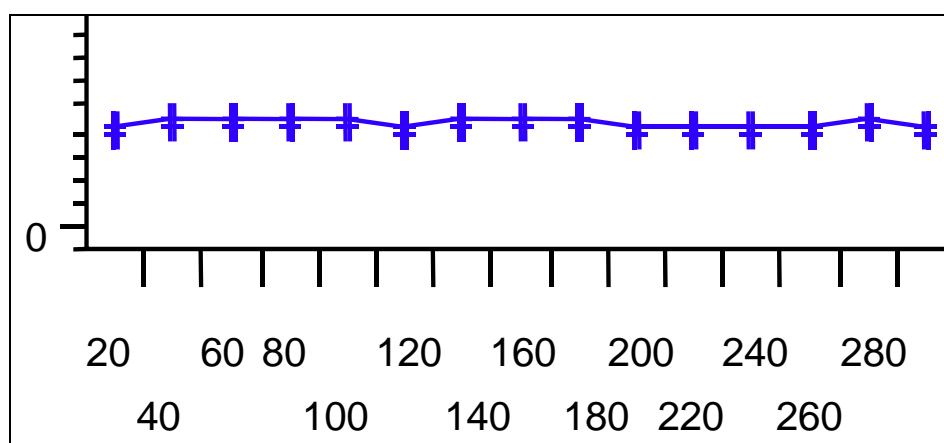


Figure B-16: SCT results for different bales in the lot.

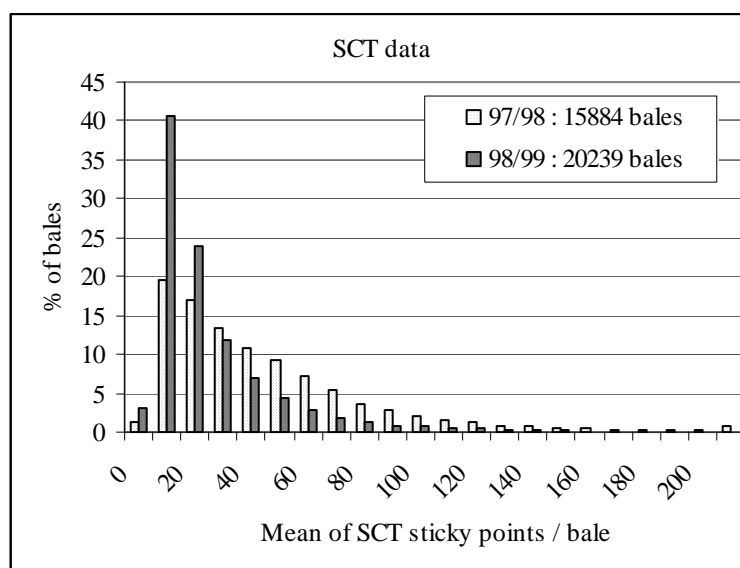


Figure B-17: Comparison of stickiness distributions in 2 crops.

B.4. Testing and evaluation of methods for establishing the degree of stickiness in cottons. Stickiness sampling methods in cotton bales: Application to the commercial classification of Sudanese cotton production using SCT

B.4.1. Introduction

This study was conducted as part of section a/ of the project entitled: “Testing and evaluation of methods for establishing the degree of stickiness in cotton”, and corresponds to outputs 1.2 and 1.3, and part of output 1.1, i.e. activities 1.1.1, 1.1.2, and 1.1.3.

Its final objective is to establish sampling and measurement methods to assess the stickiness degree of cotton bales produced in Sudan, enabling the sticky bales to be separated from the others. This will allow the uncontaminated cotton to be sold at a higher price on the international market. In other terms, the study seeks to determine methods for classifying bales according to their potential stickiness.

Two types of bale classification may be envisaged:

- quantitative classification, i.e. each bale is attributed a guaranteed stickiness score,
- qualitative classification, where the bales are separated into two categories (sticky or non-sticky) with respect to a fixed value, called the critical stickiness threshold.

At the present time, bale classification for potential stickiness would enable producers to offer spinners lots that are guaranteed trouble-free during processing. To achieve this, the bales must simply be separated into two quality categories: sticky and non-sticky. A quantitative classification system based on the number of sticky points is technically possible, but it involves a not inconsiderable cost related to the constitution and management of batches of homogeneous stickiness. On the other hand, a qualitative classification system can determine the grade of a very sticky bale after a single measurement, thus restricting the number of measurements per bale, and in consequence reducing the cost of the classification. The qualitative classification system is therefore recommended, based on the use of a critical stickiness threshold.

Before continuing with this description, it is appropriate to clearly define the notion of critical stickiness threshold. If this were to be defined as the spin-ability limit for sticky cottons, it could be extended beyond a simple measurement of the number of sticky points to other parameters, such as the size of these points, and possibly the type of sugars they contain. A spin-ability limit defined in this manner is currently under study in association with the ITF institute in the context of the second part of the project. However, the instrument used to evaluate the within-bale distribution of stickiness is unable to determine the type or the size of the sticky points. This instrument (the SCT thermodetector) was selected by the CFC when the project was ratified for at that time the SCT was the only instrument recommended by international bodies for the measurement of cotton stickiness. For these reasons, and while awaiting the results of the second part of the project, the work conducted and described in the rest of this report was based on a critical stickiness threshold defined solely by the number of sticky points measured using the SCT thermodetector.

B.4.2. Materials and methods

If cotton is to be effectively classified with regard to its stickiness, it is necessary (as explained below) to evaluate the within-bale variability of this stickiness. To do this, an investigation was conducted in samples drawn from 1000 bales: 500 roller ginned and 500 saw ginned bales were selected from the 1996 production of 100 cultivation blocks of the

Sudan Gezira board. Each block was ginned separately whereas the normal procedure is to sort production before ginning using a manual grading system, rather than by block. This change was made to ensure that the bales showed a more homogeneous potential stickiness, assuming that each block is infested in a homogeneous manner by the insects responsible for the stickiness. Ten bales per block were selected. Sixteen 80g samples per bale were drawn at the lint-slide along the pressing time.

The blocks were not chosen at random, but according to a pre-defined method. Thus, the conclusions concerning the general stickiness are applicable solely to these blocks in 1996, not to the entire cotton production of Sudan.

A 2.5g specimen was taken from each sample for a SCT test at the ARC laboratory. The 16 specimens from each bale were tested one after another by the same operator.

Unlike continuous measurement methods, sticky point counts cannot be assigned a Gaussian distribution. Repeatability does not merely relate to a variance, and within-bale probability distribution must be assessed from repeatability studies.

In brief, this distribution was inferred from theoretical considerations and the mean-variance relationship; its parameters were estimated by maximum likelihood. Likelihood ratio tests were used to check the homogeneity of the parameters. The litigation risk for bale classification was calculated from this probability distribution.

To go into deeper details, the number of sticky points is a discrete random variable obtained by the counting of points on a relatively small area of the aluminum foil. In the hypothesis of a fully randomized distribution and homogeneous sticky points density within a bale, the number of sticky points per sample, as expressed by the theory of punctual processes (Cressie, 1991; Saporta, 1990), follows a Poisson distribution with a mean for each bale. In the opposing hypothesis, the probability distribution is over-dispersed compared to Poisson's distribution. A one-sided Chi² test allows a choice to be made between these two hypotheses. Indeed, in the case of a Poisson distribution, the ratio of the sum of squares of deviates (*SCE*) to the mean of *n* measurements asymptotically follows a Chi² distribution with *n-1* degrees of freedom (Dagnelie, 1975; Fisher, 1938). For *p* bales and *n_j* measurement per bale resulting in a mean *x_{j.}*, equation B-1 gives the expression of the observed Chi² χ^2_{obs} with

$\sum_{j=1}^p (n_j - 1)$ degrees of freedom.

$$\chi^2_{obs} = \sum_{j=1}^p \left(\frac{SCE_j}{x_{j.}} \right) \quad (\text{Equation B-1})$$

When the Poisson hypothesis is rejected, the ratio of the Chi² to its number of degrees of freedom gives an estimate of the over-dispersion compared to Poisson's distribution.

The relation of the variance to the mean on a log-log scale was used as a guide to choose a probability distribution.

Among the overdispersed distributions, the negative binomial was investigated because it can be created by a wide variety of process (Johnson, 1992), and it has been observed for stickiness counts in other Cirad collaborating countries.

The negative binomial distribution with mean *m* and shape parameter *k*, is the distribution of the random variable *X* for which

$$P(X = x) = \frac{\Gamma(k + x) m^x k^k}{\Gamma(x + 1) \Gamma(k) (m + k)^{(k+x)}} \quad (\text{Equation B-2})$$

with gamma (Γ) being the generalized integral defined by:

$$\Gamma(k) = \int_0^\infty x^{k-1} \exp(-x) dx \quad (\text{Equation B-3})$$

Its variance is $\sigma^2 = m + m^2/k$

Each bale has its own mean stickiness m_j , whereas the parameter k is supposed to be the same for all bales.

When estimating the parameters on a set of p bales, the arithmetic mean $x_{j\cdot}$ is a good estimate of the parameter m_j . On the other hand, the shape factor k can be estimated using different ways, from which the method of the maximum of likelihood is the most precise. This method consists in evaluating the maximum of the function L :

$$L = \prod_{j=1}^p \prod_{i=1}^{n_j} \frac{\Gamma(k + x_{ji}) (x_{j\cdot})^{x_{ji}} k^k}{\Gamma(x_{ji} + 1) \Gamma(k) (x_{j\cdot} + k)^{(k+x_{ji})}} \quad (\text{Equation B-4})$$

In practice, it is easier to estimate the inverse of k , because the estimation of the quantity $\alpha = 1/k$ is less biased and gives more symmetrical confidence intervals around α . than that of k

A one-sided maximum likelihood ratio test allows to check for the homogeneity of the k coefficient within a group of p bales. Indeed, if L is the maximum of likelihood which is obtained considering that all the bales have the same k coefficient, and L_j the one obtained with a k_j for every bale or group of bale taken separately, then the quantity $-2(\log L - \sum \log L_j)$ is a Chi² with $p - 1$ degrees of freedom.

B.4.3. Results

An analysis of variance on the square root of the mean number of sticky points was performed to detect any difference of mean level between counters. It showed clear differences between counters ($P < 0.0001$). Although bales were not allotted at random between the different counters, this suggests that some counters may detect more sticky points than others. As a consequence, SCT does not seem fully adapted to commercial classification, as countings made by a person may differ from those made by another person. However, we investigated the within-bale variability.

The scatter plot of log-transformed variance against log-transformed mean shows that variance increases with the mean (Figure B-18). On the opposite, if sticky points were randomly distributed within a bale, the number of sticky points for any given bale would follow a Poisson distribution for each bale with a variance equal to its mean. This Poisson hypothesis was also rejected at the 0.0001 level by the Chi² over-dispersion test.

The scatter plot of log(variance) versus log(mean) (Figure B-18) shows that the relationship between mean and variance, as modeled with a negative binomial distribution, is not satisfactory. Here, two sub-clouds of points may be observed: one above the curve, the other below. The second is even below the bisecting line (dashed), which corresponds to the most restricted dispersion that can be imagined in a situation where the sticky points are distributed

in a completely random fashion on the fiber of the entire bale. This underdispersion phenomenon should not be observed, even with a completely random distribution of sticky points. No explanation of this phenomena can be brought by the ginning method which is used as displayed in Figure B-19 where 'roller' and 'saw' ginned clouds results are superimposed.

However, under-dispersion can be observed when all stickiness measurements for the same bale are made one after another. This phenomenon may be attributed to observer memory, i.e. each time the points are counted, the operator remembers the counts he/she has just determined for other samples from the same bale.

The upper cloud covers the most variable measurements. It was separated from the lower cloud by an over-dispersion test with an alpha type I error of 1% (Figure B-20). This over-dispersion may be the result of sticky points distributed as clumps, or may be due to incomplete mixing of the fibers during ginning.

After assuming that the measurements in the upper cloud were not affected by operator memory, we sought to adjust a negative binomial distribution solely for the points showing significant over-dispersion. However, this adjustment was not satisfactory either, as shown in Figure B-20. No conclusion can therefore be drawn from the measurements made in the 1000 bales concerning the probability distribution of SCT counts, apart from the hypothesis of an operator memory effect.

In order to test this hypothesis and to evaluate the within-bale distribution of SCT sticky points even in the presence of memory effect, two other experiments were conducted at CIRAD on a sub-set of the 1000 bales. The first involved the first 30 bales and was not randomized. The second, conducted during the placement of Dr Abdel Rahman in Montpellier, involved 30 other bales chosen at random. In this experiment, 16 measurements of each bale were distributed at random between two operators and were analyzed in a random order.

In the randomized experiment, a possible difference of level between the two operators was tested with an appropriate log-linear model (listing 1). This does not affect much the overdispersion index that drops from 5 to 4.86. The operator effect is not significant ($P=0.15$), when taking into account the operator effect. Therefore, the within-bale variances were estimated ignoring this difference of level.

When considering the measurements made at CIRAD, the scatter plot of $\log(\text{mean})$ against $\log(\text{variance})$ shows that the over-dispersion is more pronounced in the randomized experiment (Figure B-21) than in the non-randomized experiment (Figure B-22). The less pronounced over-dispersion noted for the non-randomized measurements was attributed to the operator memory effect.

The counts made by the ARC were even less dispersed than those observed at CIRAD in the absence of any randomization. This suggests that the operator memory effect introduced substantial bias into the results in routine conditions.

This calls for the following recommendation: when performing several measurements on the same sample with SCT, it is important to interleave the specimen from the same sample with specimen from other samples in a randomized order, in order the operator ignores what sample he is analyzing at the time he counts.

No level difference between operators was detected in these later experiments thanks to the good training of the operators and the periodical check of their readings on reference cottons. We recommend these precautions to be used as well in routine tests.

When considering the randomized measurements, an adjustment using a negative binomial distribution gives satisfactory results for the relationship between the mean and the variance, regardless of whether the k parameter is estimated by non-linear regression or by maximum likelihood. Thus, although a likelihood ratio test showed that the k parameter is heterogeneous ($\chi^2=6.7322$ for 1 df, $P=0.0095$), a negative binomial distribution of parameter $k=10.8$ is the best approximation that can be established by this study.

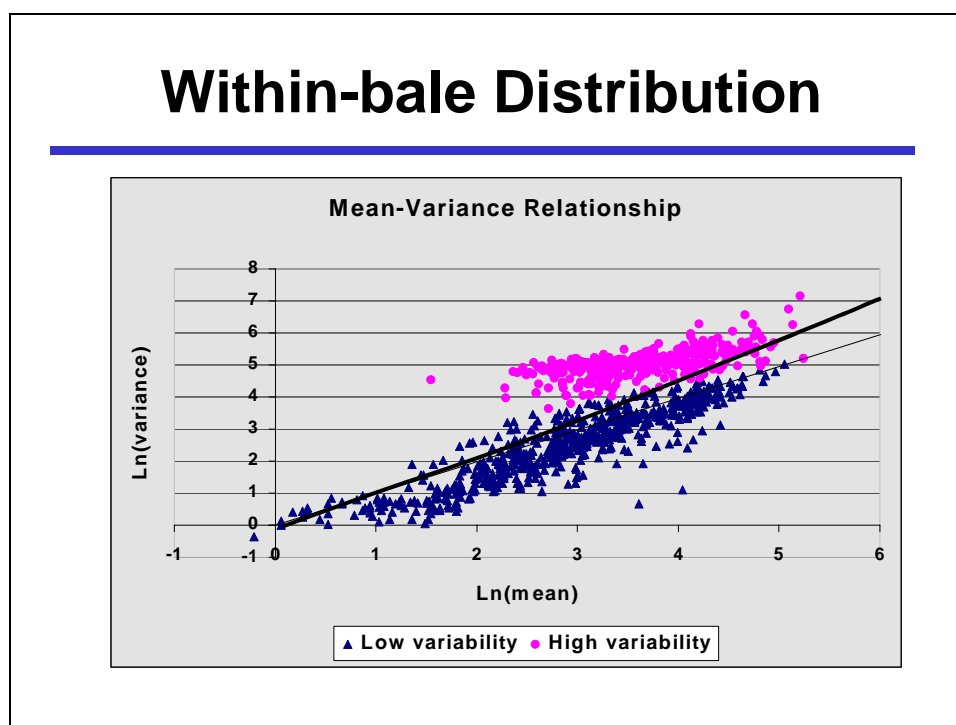


Figure B-18: Relationship between within bale variance and bale mean on SCT measurements on 1000 bales sampled from 1996 production of 100 blocks of the Sudan Gezira board. The solid line shows the theoretical variance x mean relationship for negative binomial distributions with a common k estimated on all the bales.

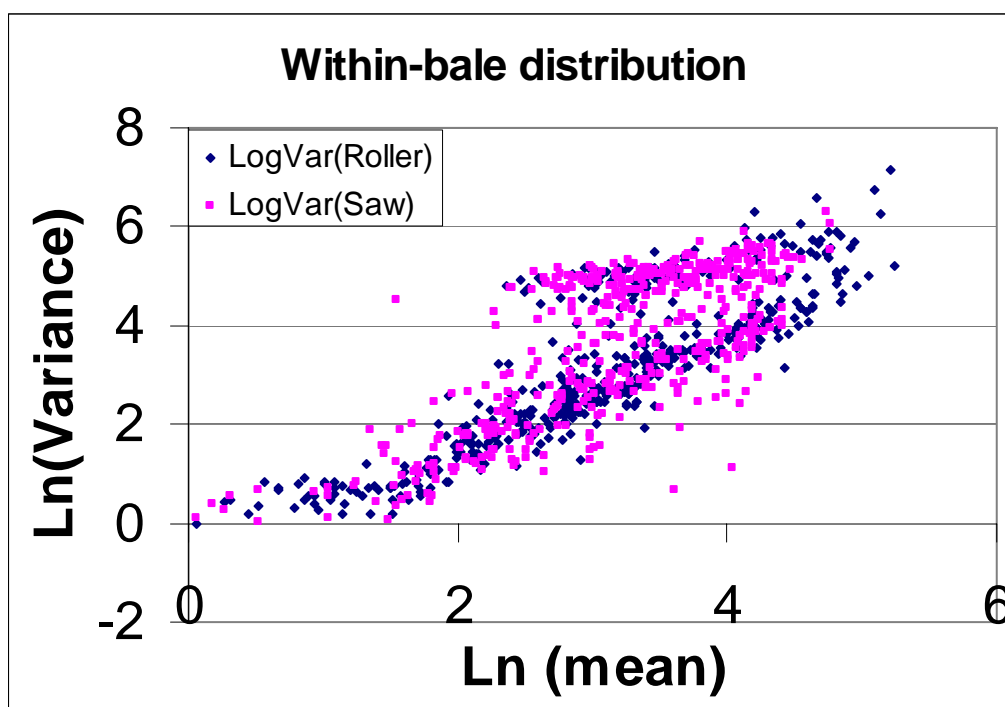


Figure B-19: Same relation as previous figure with a classification according to the ginning method (roller / saw).

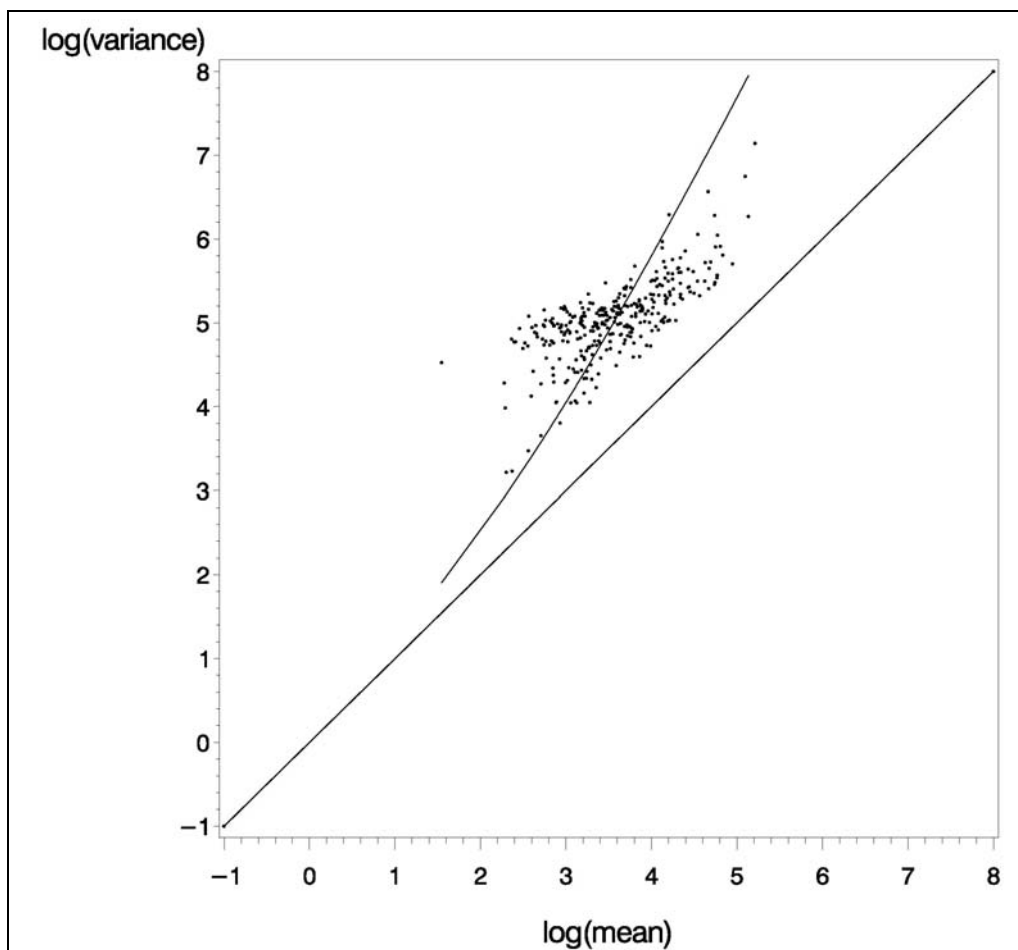


Figure B-20: Relationship between within-bale variance and bale mean on over-dispersed SCT measurements. Over-dispersed bales are selected from the 1000 bales, after a chi-square over-dispersion test with $\alpha = 0.01$. The solid line shows the theoretical variance x mean relationship for negative binomial distributions with a common k of 10.81, estimated on the over-dispersed bales.

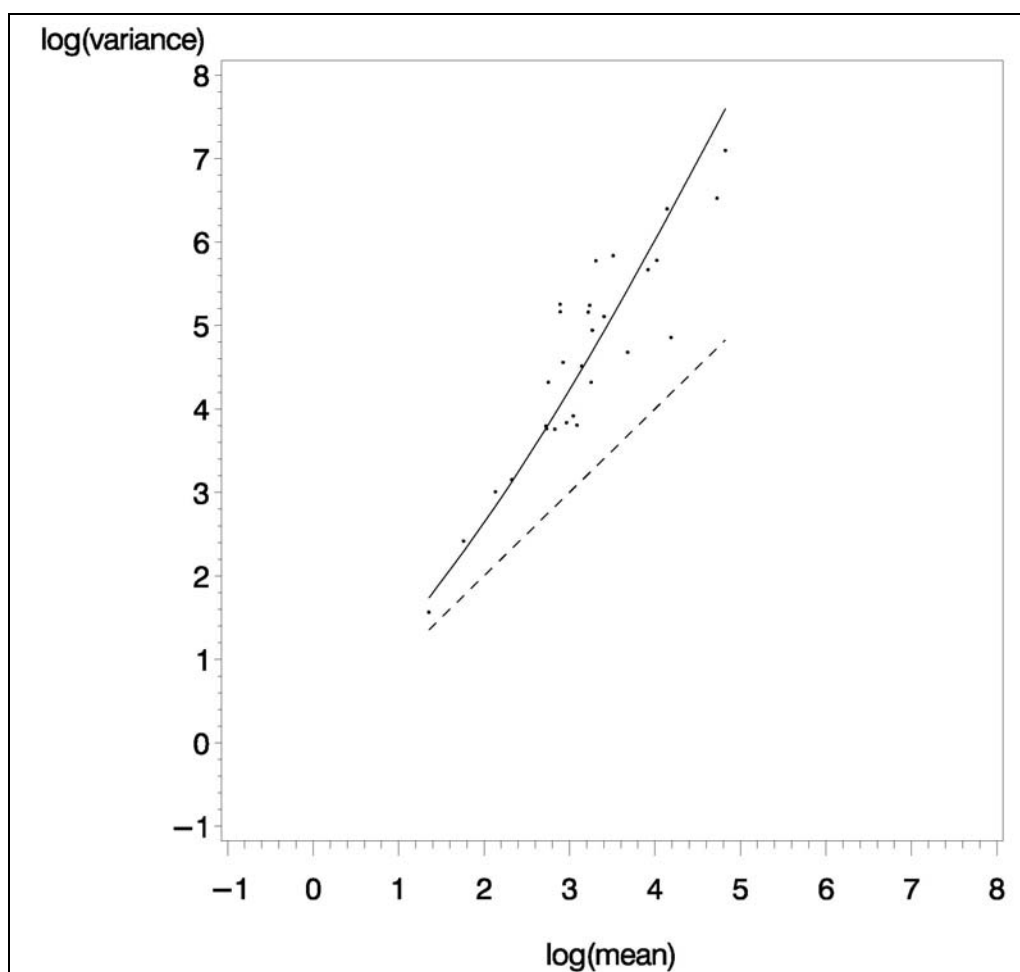


Figure B-21: Relationship between within-bale variance and bale mean on SCT measurements in a randomized experiment carried out at Cirad on 29 bales of Sudanese cotton. The bisecting line shows the theoretical variance x mean relationship for Poisson distributions. The solid line shows the theoretical variance x mean relationship for negative binomial distributions with a common k estimated on the 29 bales.

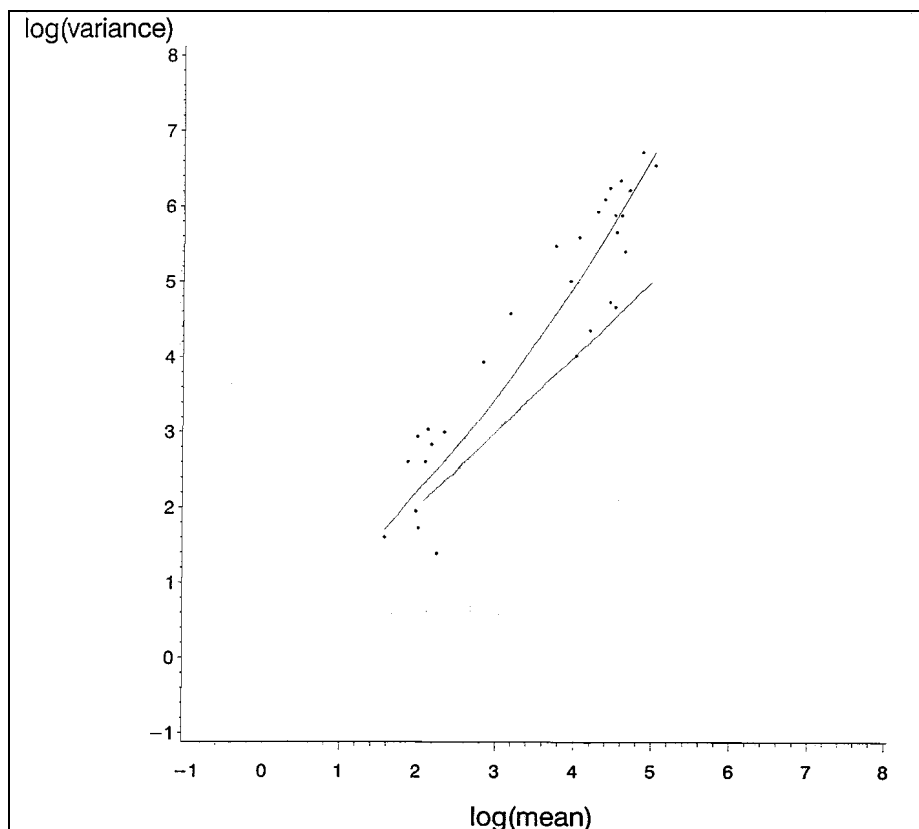


Figure B-22: Relationship between within-bale variance and bale mean on SCT measurements in a non-randomized experiment carried out at Cirad on 30 bales of Sudanese cotton. The bisecting line (dashed) shows the theoretical variance x mean relationship for Poisson distributions. The solid line shows the theoretical variance x mean relationship for negative binomial distributions with a common k estimated on the 30 bales.

Listing 1:

LOG-LINEAR MODEL WITHOUT OPERATOR EFFECT: OVERDISPERSION IS 5.0066

The GENMOD Procedure

Model Information

Data Set	WORK.EFFETOPE
Distribution	Poisson
Link Function	Log
Dependent Variable	SCT SCT
Observations Used	480

Class Level Information

Class	Levels	Values
BALLE	30	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30

Criteria For Assessing Goodness Of Fit

Criterion	DF	Value	Value/DF
Deviance	450	2252.9589	5.0066
Scaled Deviance	450	2252.9589	5.0066

LOG-LINEAR MODEL ON RANDOMISED EXPERIMENT

OVERDISPERSION, AS MEASURED BY DEVIANCE/DF SLIGHTLY DROPS DOWN TO 4.86

OPERATOR EFFECT IS NOT SIGNIFICANT (P=0.1488)

BALE*OPERATOR INTERACTION IS NEARLY SIGNIFICANT (P=0.0660)

The GENMOD Procedure

Model Information

Data Set	WORK.EFFETOPE	
Distribution	Poisson	
Link Function	Log	
Dependent Variable	SCT	SCT
Observations Used	480	

Class Level Information

Class	Levels	Values
BALLE	30	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
OPERATEU	2	1 2

Criteria For Assessing Goodness Of Fit

Criterion	DF	Value	Value/DF
Deviance	420	2042.4133	4.8629
Scaled Deviance	420	420.0000	1.0000
Pearson Chi-Square	420	2026.3341	4.8246
Scaled Pearson X2	420	416.6935	0.9921
Log Likelihood		8785.9569	

Algorithm converged.

LR Statistics For Type 1 Analysis

Source	Deviance	Num DF	Den DF	F Value	Pr > F	Chi-Square	Pr > ChiSq
Intercept	11113.9683						
BALLE	2252.9589	29	420	62.83	<.0001	1822.17	<.0001
OPERATEU	2242.8206	1	420	2.08	0.1495	2.08	0.1488
BALLE*OPERATEU	2042.4133	29	420	1.42	0.0752	41.21	0.0660

B.5. Stickiness variability and feasibility of a commercial classification using H2SD

B.5.1. Objective

This experiment was designed to highlight the within-bale stickiness distribution and its parameters in order to evaluate the number of samples and the number replicates required for a representative estimate of the stickiness potential of a given cotton bale.

B.5.2. Materials and methods

To evaluate this distribution, 100 bales were selected from Sudanese production: 50 were roller-ginned and 50 were saw-ginned. During the ginning process of these bales, 16 layers of cotton were sampled in every bale

It is important to note that these bales were selected to represent a broad stickiness range and are therefore not representative of the actual extend of stickiness in Sudanese production. We will highlight later the importance of sampling representativity in this procedure. After been conditioned in normal conditions (65% relative humidity and 21°C), the samples were H2SD tested using a fully randomized design.

B.5.3. Results and discussion

B.5.3.1. Within-bale distribution of stickiness

B.5.3.1.1. Probability distribution of the number of sticky points

Considering the 100 test bales with 16 measures each, apart from some missing samples, the observed χ^2 based on equation 1 is equal to 7213 with 1492 degrees of freedom. The hypothesis of within-bale Poisson's distribution is then rejected at 0.01% level. The over-dispersion index, which is the ratio of the variance to the mean, is around 4.84.

This relation seems quadratic when observing the regression logarithm of the variance to the one of the mean (Figure B-23). Such a relation suggests a negative binomial distribution.

The maximum likelihood estimation of k , as using SAS software, converged to an homogeneous value of $k = 9,43$.

The within-bale distribution of the number of sticky points is then negative binomial with shape parameter $k = 9,43$ for the 100 bales sample we tested.

As we evaluated the within-bale distribution, we will now see its application to a qualitative classification of the bales.

B.5.4. Litigation risk in qualitative classification: definition and control method

The variability of the measurements made determines the risk involved in commercial classification, i.e. the risk that a bale classified as non-sticky by the supplier is then evaluated as sticky by the purchaser. This risk can be reduced to an acceptable level by classifying more strictly than in subsequent evaluations.

A bale is classified by reference to a classification threshold: if the stickiness measured is less than or equal to the threshold, the bale is classified as non-sticky. If the stickiness is greater than the threshold, the bale is classified as sticky. However, the different measurements made for the same bale do not always give the same results, as already noted in the variability study. Therefore, the same bale could be classified at some point as non-sticky and at another as sticky. This is a potential cause of litigation between the seller and the purchaser.

This idea is illustrated in Figure B-24. Here, the classification threshold is set at 10, i.e. bales with 11 points or more are classified as sticky. If we consider a bale with a true potential stickiness corresponding to a mean of $m=12$ sticky points, and showing a negative binomial distribution (as seen in the randomized experiment), equation 1 can be used to calculate the probability of observing exactly $X=0, 1, 2$, etc. sticky points. These different probabilities are plotted against X .

In this precise case, it can be seen that the probability of classifying the bale as non-sticky (solid bars) is nearly the same as the probability of classifying the bale as sticky (dashed bars). To be more precise, the probability of classifying the bale as non-sticky is 0.428.

If the purchaser adopts the same classification threshold and the same number of measurements, he will have a probability of $1-0.428=0.572$ of classifying the same bale as sticky. To result in litigation, the supplier must have classified the bale as non-sticky and the purchaser must have classified the same bale as sticky. As these two classifications are independent, the probability of both events corresponds to the product of their individual probabilities. The risk of litigation is therefore $0.428 \times 0.572 = 0.24$.

Such a risk can have considerable economic consequences and is therefore unacceptable. It can even be demonstrated that the risk may reach a maximum of 0.25. This occurs when the classification threshold is exactly equal to the distribution median. This result is independent of the probability distribution.

The risk for any given threshold varies in relation to the potential stickiness of the bale, as shown in Figure B-25.

In practice, the potential stickiness of the bale is unknown when it is classified. When classifying an entire production of bales, the litigation risk is the mean risk over all the bales, which depends on the probability distribution of the stickiness in the population.

As this distribution is unknown, no calculations can be made based in advance on this overall risk, but we do know that its upper limit is the maximum risk. Therefore, as we are unable to base calculations on this overall risk, we can use the maximum risk. If this is set at a reasonably low value, a low litigation risk can be expected.

One method of lowering the maximum risk is to be more strict when classifying than when evaluating. To guarantee that an evaluation of the bales will practically never give a stickiness reading higher than the limit required by the spinner (called the evaluation threshold), the producer must classify his bales using a lower threshold (called the classification threshold).

For example, if the evaluation threshold is always set at 10 sticky points, but the classification threshold is set at 3 sticky points, the risk of litigation for a bale with potential stickiness of 12 points is only $0.0237 \times (1 - 0.428) = 0.0086$, i.e. 1.4%.

The maximum risk has been calculated with respect to both the classification and evaluation thresholds, with one or two replications. Figure B-26 and Figure B-27 show isolines for this risk in relation to the classification and evaluation thresholds.

For example, if the valuation threshold is set at 15 sticky points, then a classification threshold of 3 sticky points would result in a maximum risk of approximately 1%. With 2 measurements per bale, the classification threshold can be safely raised to 6 sticky points without any increase in the maximum risk.

To make calculations more formal, the litigation is the conjunction of two independent events:
A: the bale is classified as non-sticky;

\bar{B} : the bale is evaluated as sticky.

The litigation risk, as defined above, can be calculated as follows: expressing the mean from the total X of the r measurements, we get the probability of events A and B:

$$\begin{aligned} P(A) &= P(M \leq t_s) = P(X \leq rt_s) \\ P(B) &= P(M' \leq t_s) = P(X \leq rt_s) = P(A) \end{aligned} \quad (\text{Equation B-5})$$

Hence, $P(\bar{B}) = 1 - P(A)$.

The total X follows a binomial distribution with parameters rm and rk , since the counts are independent [Johnson, Kotz et Kemp, 1992]. This gives:

$$RL(m) = F(rt_s)(1 - F(rt_s)) \quad (\text{Equation B-6})$$

The litigation risk RL in this formula depends on the mean m , the number of measurements r and the stickiness threshold t_s . For a given threshold t_s and a given number of measurements r , this risk varies with the mean m and goes through a maximum as given in the example (Figure B-25). This risk is specific to each individual bale.

Its maximum with respect to m is the same as the maximum with respect to $P(A)$ because this probability is a strictly decreasing function of m . The derivation of RL gives:

$$\frac{\partial RL(m)}{\partial P(A)} = -2P(A) \quad (\text{Equation B-7})$$

from which we can deduce a maximum $RL_{max} = 0.25$ when the threshold is a median of the distribution. This risk is too important for a classification because the cost of the claims by the purchasers would be too high.

One way to limit this maximum risk for the producer is to fix a classification threshold t_c lower than the one imposed by the purchaser that we called evaluation risk l_v . In these conditions, the litigation risk expression, $RL(m) = P(A)[1 - P(B)]$, becomes :

$$RL(m) = \sum_{x=0}^{r_c} \frac{\Gamma(rk+x)(rm)^x (rk)^{rk}}{\Gamma(x+1)\Gamma(rk)(rm+rk)^{(rk+x)}} \left[1 - \sum_{x=0}^{r_v} \frac{\Gamma(rk+x)(rm)^x (rk)^{rk}}{\Gamma(x+1)\Gamma(rk)(rm+rk)^{(rk+x)}} \right] \quad (\text{Equation B-8})$$

B.5.4.1.1. Litigation risk for an entire production

We are interested by the averaged litigation risk for a complete production, this average is weighted by the probability density function of the averaged level of per bale $f(m)$. The global risk RG is:

$$RG = \int_0^{\infty} RL(m) f(m) dm \quad (\text{Equation B-9})$$

This risk RG should be evaluated by a specific study for each country and to its production environment. This specific study require a sampling procedure taking in account the statistical representativity of the entire crop production.

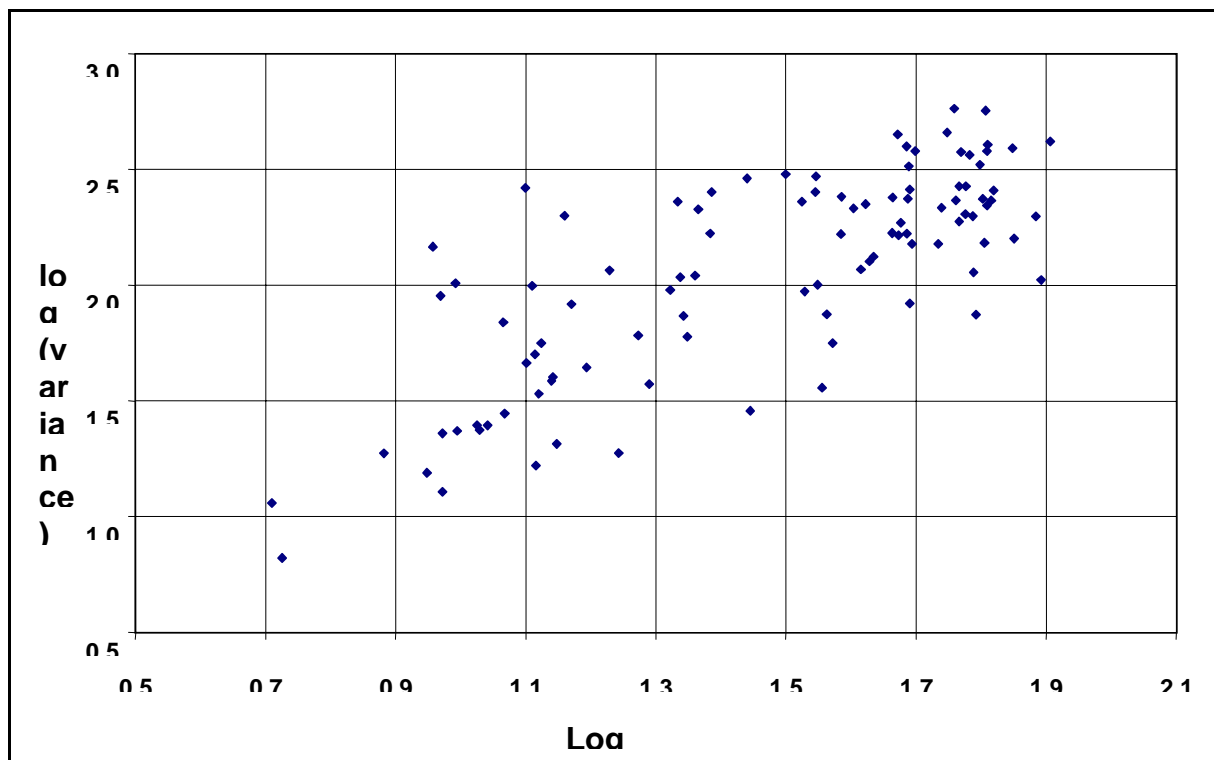


Figure B-23: Relation Variance vs Mean of the number of sticky points as measured by H2SD.

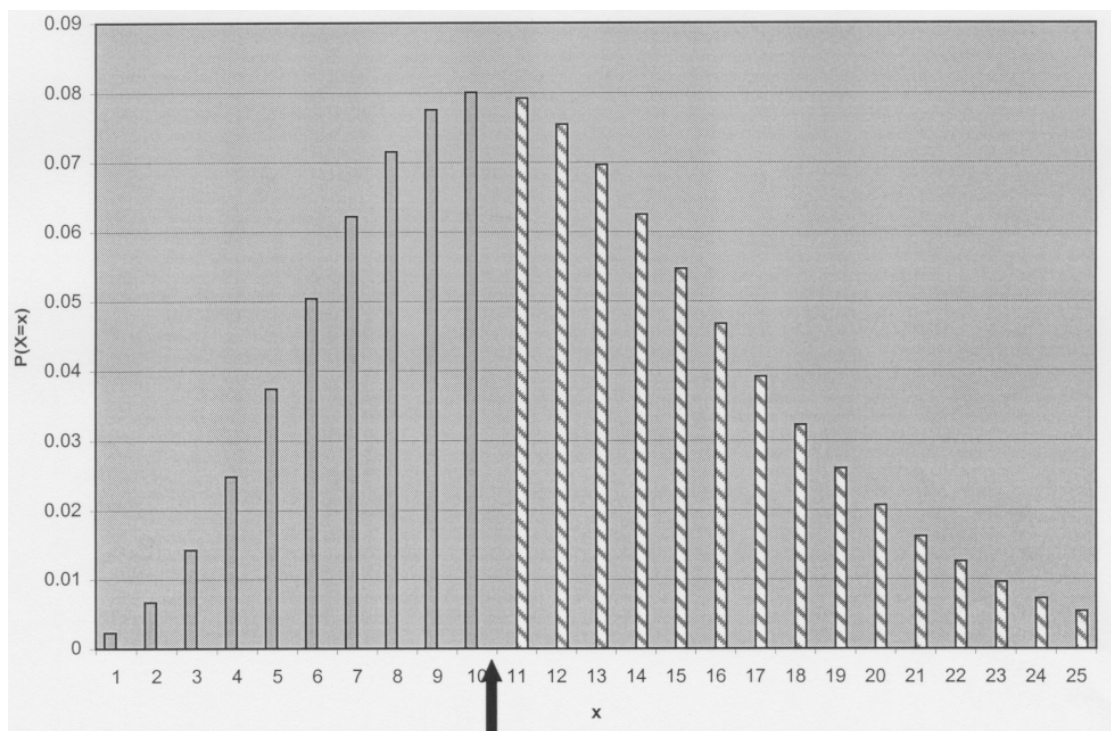


Figure B-24: Negative binomial probability distribution of sticky point numbers, mean = 12 and $k = 9.43$.

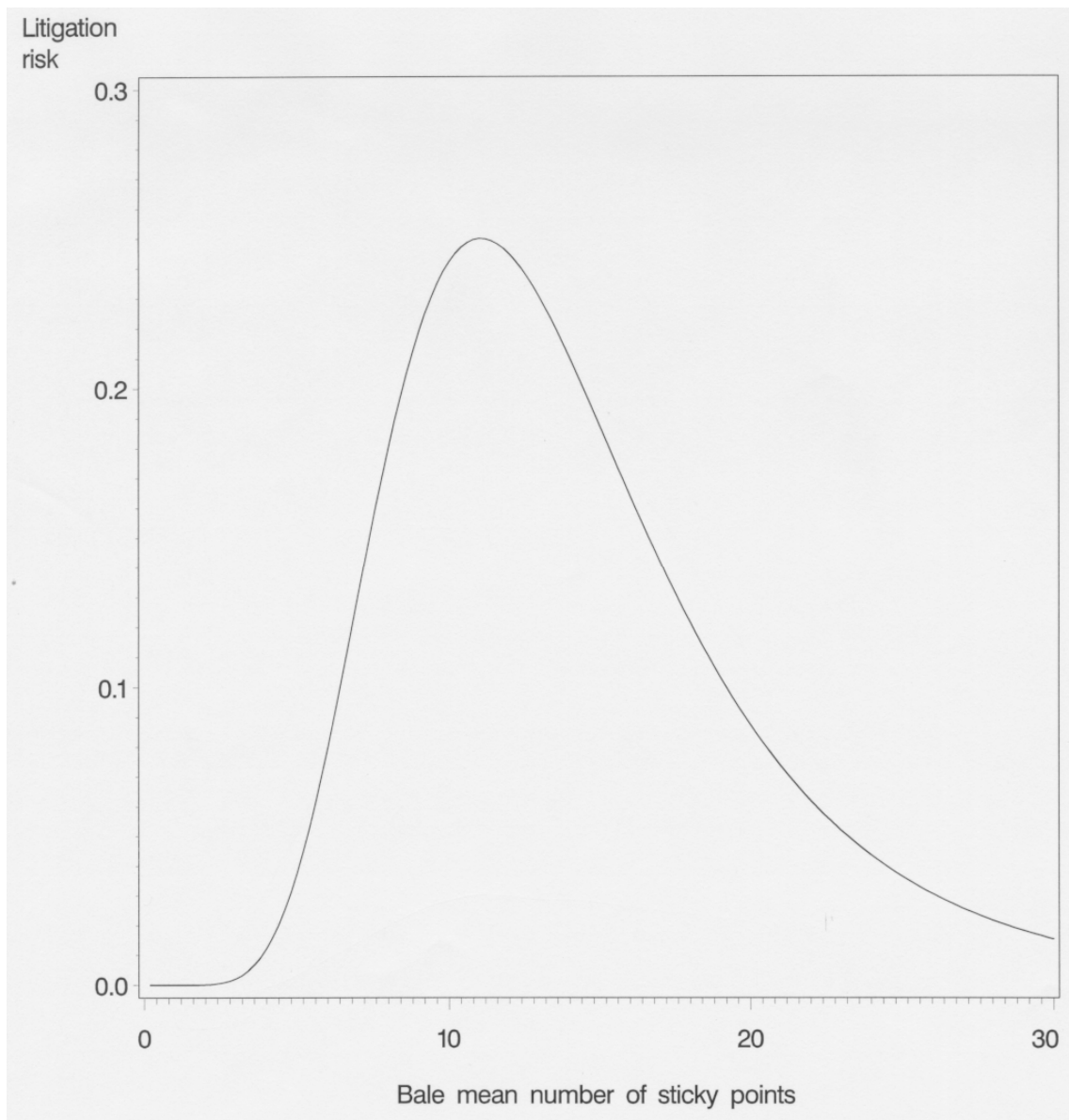


Figure B-25: Litigation risk when classification threshold = evaluation threshold = 10 sticky points. Negative binomial distribution, $k = 9.43$, $R=1$ measurement per bale.

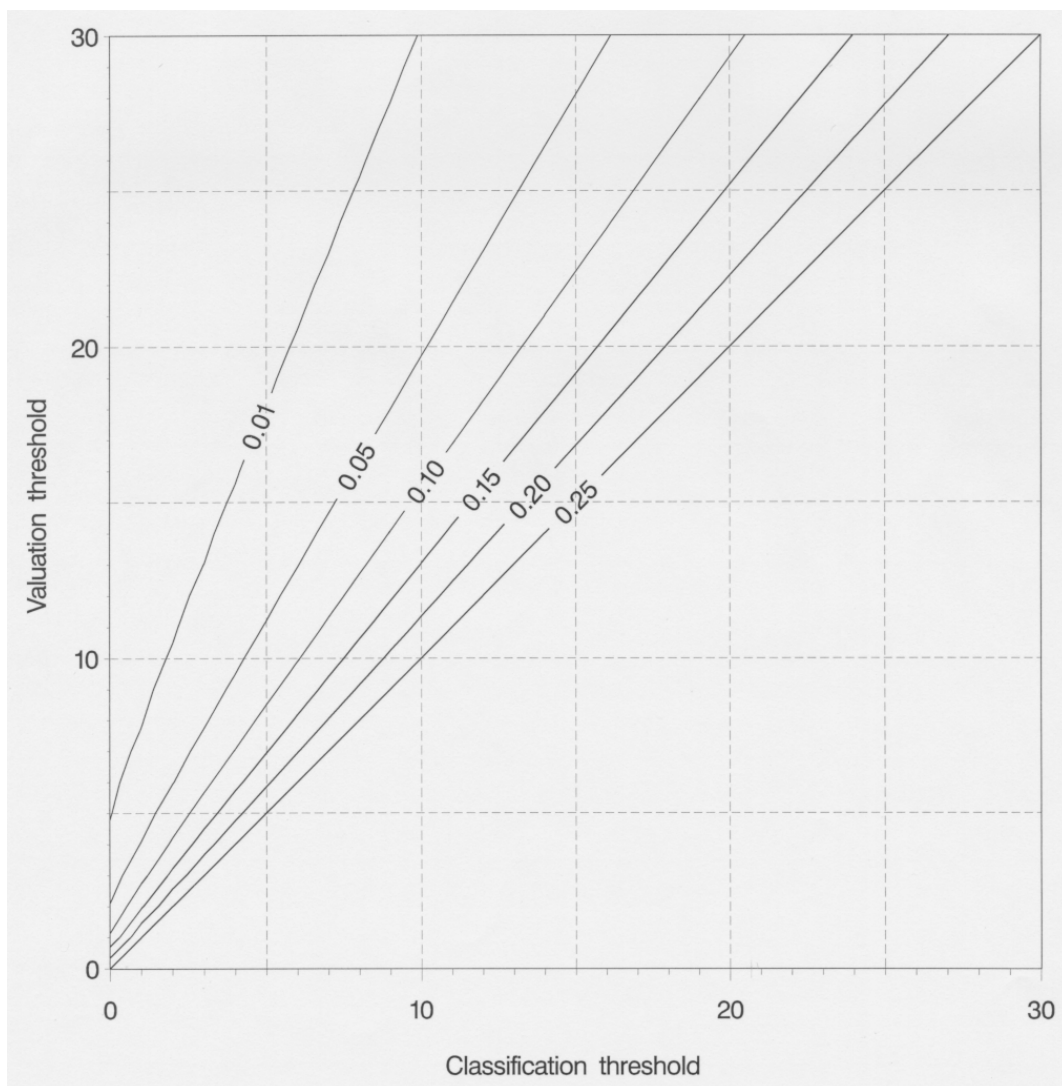


Figure B-26: Evaluation threshold t_v as a function of the classification threshold t_s in the case of a negative binomial distribution with $k = 9.43$ and two H2SD measurements per bale ($r=1$).

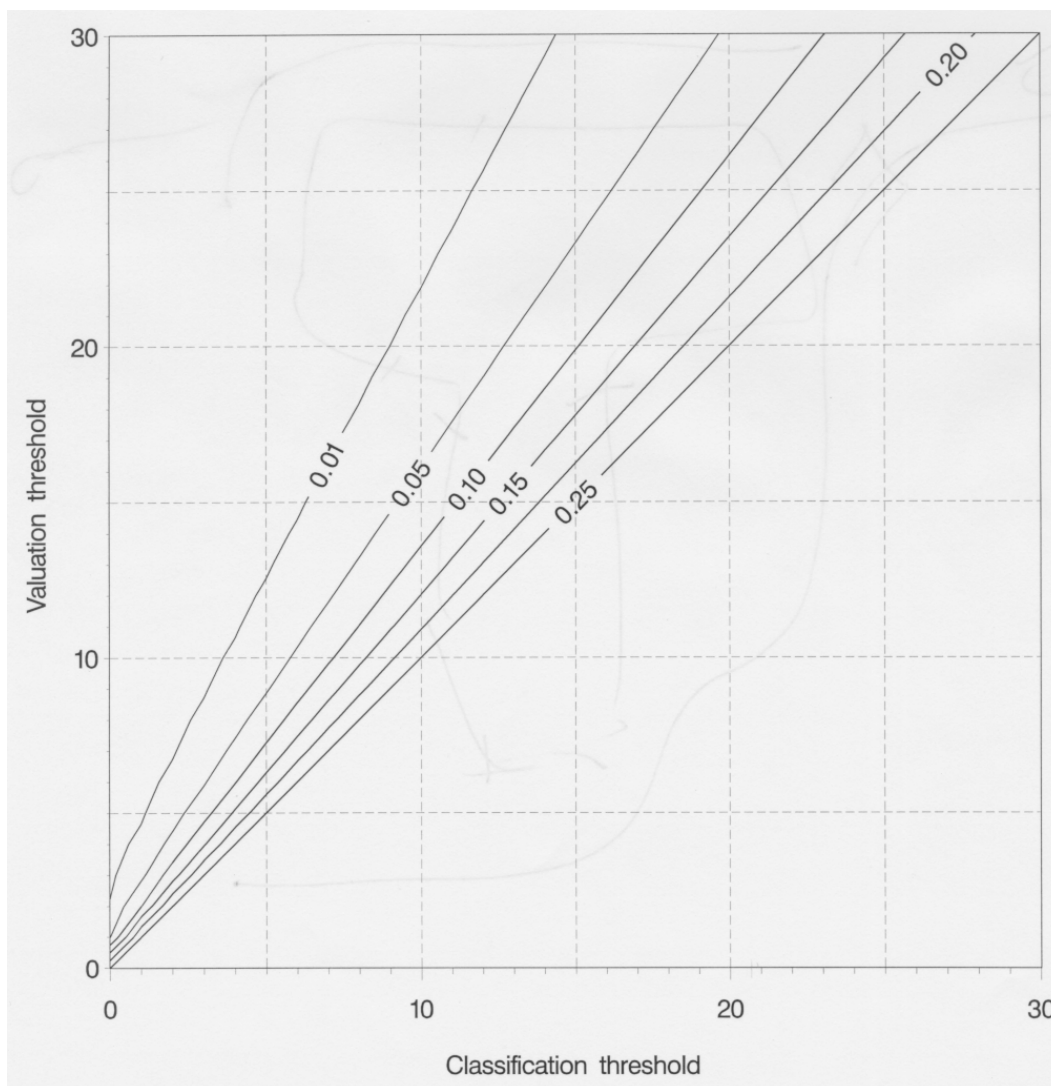


Figure B-27: Evaluation threshold lv as a function of the classification threshold ts in the case of a negative binomial distribution with $k = 9,43$ and two H2SD measurements per bale ($r=2$).

B.6. Complementary experiment: Extra experimentation with 7680 samples taken in the whole country.

B.6.1. Objective:

To study the within-bale variability of stickiness, as well as other sources of variability and deduce a possible litigation risk for applying it during a classification process.

B.6.2. Material and method:

The next step is now to confirm these information through a large scale testing. Thus, during our visit to Sudan in December 1998, we proposed and agreed the following experiment with all the persons that are concerned with the Project. The following choices have been made to represent the Sudanese cotton production. Table B-1 gives the information which serve as basis for our final choice.

In the following text, the gin factories will be called 'gins' (even if some counting 96 or more gin-stands in case of roller ginning for instance).

The main information concerning the Sudanese cotton production are given in Table B-1 and Table B-2.

Table B-1: Cross tabulation by variety and geographic zone.

	Geographic zone			% of the production
	Zone1	Zone 2	Zone 3	
Production	25%	25%	50%	
Variety 1	17%	17%	66%	75%
Variety 2	0%	0%	100%	25%

Table B-2: Repartition if the gins within the cotton area.

	Geographic zone		
	Zone1	Zone 2	Zone 3
Type of ginning and	Saw	Saw	Saw: 1
Total number of gins	3	4	Roller: 12

To get a representative sample of the Sudanese production, in our experiment, and with respect to an economical limit, we chose the following protocol:

- 8 gin factories were sampled among the 20 installed in Sudan, taking care of the variety and of the repartition roller vs saw gin. The selected gins have been chosen to have the highest production levels to meet a better representativity of the production.
- in each gin, we selected 30 lots within their production during the ginning crop 1998/1999.
- we made the assumption that any lot counts exactly 100 bales in all cases.

- for each lot, we sampled 1 bale every 50 bales. In practice, the bales labeled as 25, 75, 125, 175, ..., (every 50 bales) were sampled.
- for each bale retained, 16 different layers were sampled taking one sample of 50 grams on every layer.
- for each of these sample, we got the relevant information to properly analyze the collected data.

To make the sampling easier, samples were taken in the lint slide prior to bale packing.

With all the samples are taken, we got:

$8 \text{ gins} * 30 \text{ lots/gin} * 2 \text{ bales/lot} * 16 \text{ samples/bale} = 7680 \text{ samples.}$

These samples were sent to CIRAD in Montpellier. CIRAD tested all these samples using H2SD device in a randomized design per gin. Reference cottons were also randomly analyzed in the series of Sudanese samples to check the H2SD's consistency in the results.

B.6.3. Results and discussion

No significant trend appears in the results for the reference cottons (Figure B-28). This indicates that H2SD reads the same (within the confidence intervals) for given cottons along the time as it is expected for such instrument. Thus, a good confidence can be assumed for the following results.

Detailed analysis of the stickiness has been done per gin (Figure B-29 to Figure B-36). We can observe that some production zones are non-sticky while other are sticky at different degrees.

In summary, we can conclude that:

- Some producing zones induce higher levels of stickiness while some other keep a low level of stickiness.
- There is a highly significant varietal effect.
- The type of ginning do not explain any variation in the level of stickiness.

Important notice: Fibers from one variety are mainly used for combed process, while fibers from the other variety are used in carded spinning. Thus, even if the fibers used in the combed process have a low stickiness level compared to the other variety ones, problems can appear during the specific processing for the longest fibers, and deteriorate its image in terms of stickiness.

It appears that around 34% of the bales for that crop, assuming that this sampling is representative of the production, has a stickiness level under 30 points H2SD (which is already sticky, Figure B-37).

Comparable conclusions can be drawn concerning the within-bale stickiness variability. Figure B-38 gives the relations $\log(\text{variance})$ as function $\log(\text{mean})$ for the complete set of samples. Figure B-39 gives the relations $\log(\text{variance})$ as function $\log(\text{mean})$ for the different production zones. Different patterns appear indicating that a unique statistical distribution cannot describe the observed data. In consequence, a litigation risk for the entire country cannot be deduced.

The observed data could be fitted with a binomial negative distribution for this set of data as well as it was possible for the 100 bales data set. The shape factor was changed to $k=9.78$. This means that it would be possible to establish tables to set both classification and

evaluation threshold. However, the Figure B-38 shows some kind of saturation for the highest values of stickiness that could affect the shape factor estimation. Indeed, when we only take into account the population of the bales having a stickiness level lower than 10 to 20 H2SD sticky points, this shape factor is changed to 3.17. The k shape factor value changes according to the within-bale stickiness distribution, which depends on production conditions.

Further sampling and testing will be necessary to set this shape factor. Since significant differences appears between gins in the actual production conditions, it may be necessary to improve these production conditions prior first, then a new sampling and testing operations will be required to finally fix the law and its parameter in order to assess classification and evaluation thresholds.

A significant effect is shown for the gin location onto stickiness as illustrated in Figure B-40.

B.6.4. Conclusion

These results demonstrate that a wide range of stickiness can be recorded within Sudan. Some areas seems to have greater sensibility to insect infestation, that may be explained by the location and the variety, even if other factors can interact.

Since significant differences appears between gins in the actual production conditions, it may be necessary to improve these production conditions prior first, then a new sampling and testing operations will be required to finally fix the law and its parameter in order to assess classification and evaluation thresholds.

The early picking appears to be the most effective solution as deduced from discussion in Wad Medani end of 2000. However, this will require appliance of different combined solutions to fit against stickiness.

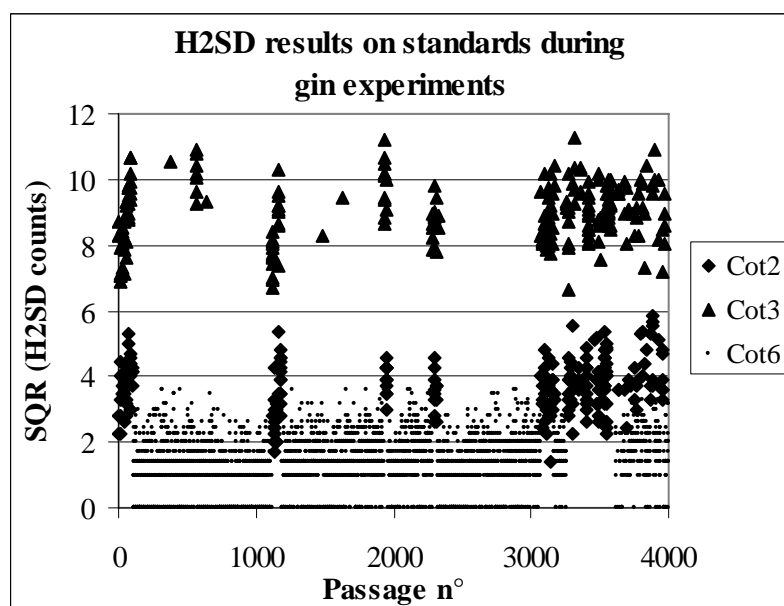


Figure B-28: Results on 'reference cottons'.

H2SD : Gin 1

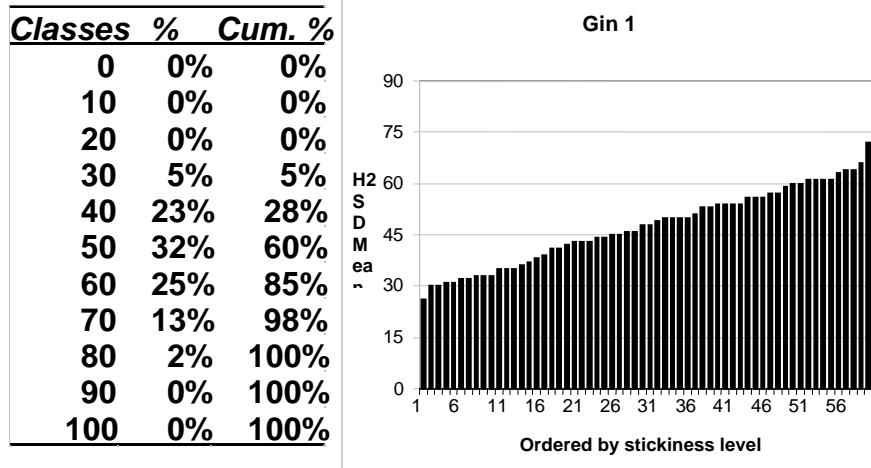


Figure B-29: Stickiness results: gin 1.

H2SD : Gin 2

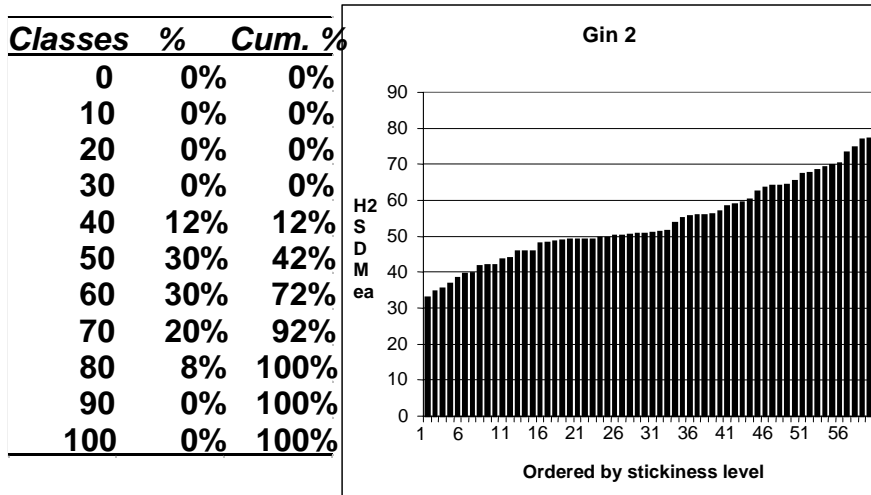


Figure B-30: Stickiness results: gin 2.

H2SD : Gin 3

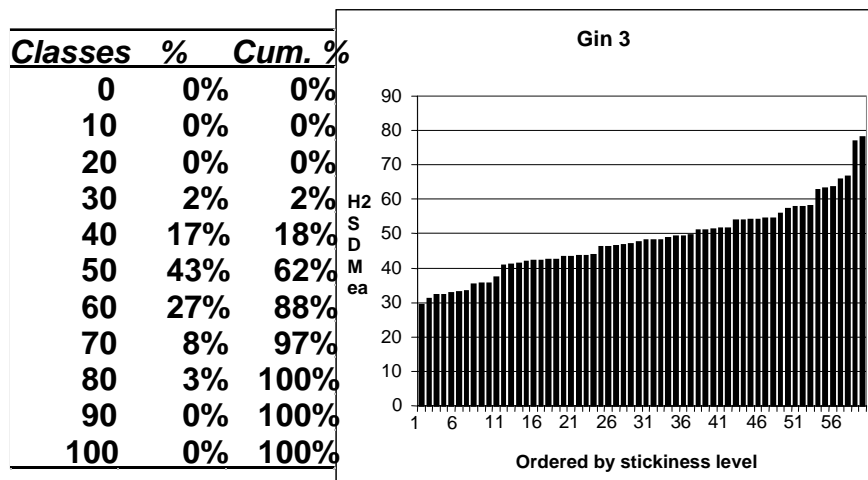


Figure B-31: Stickiness results: gin 3.

H2SD : Gin 4

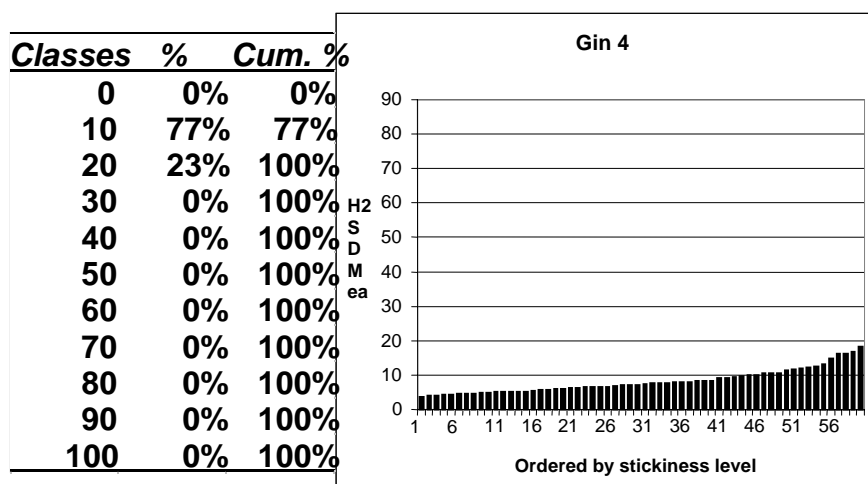


Figure B-32: Stickiness results: gin 4.

H2SD : Gin 5

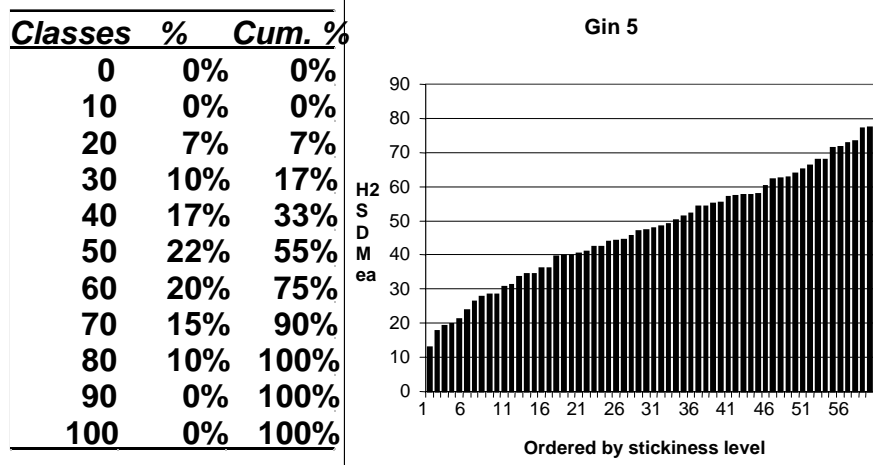


Figure B-33: Stickiness results: gin 5.

H2SD : Gin 6

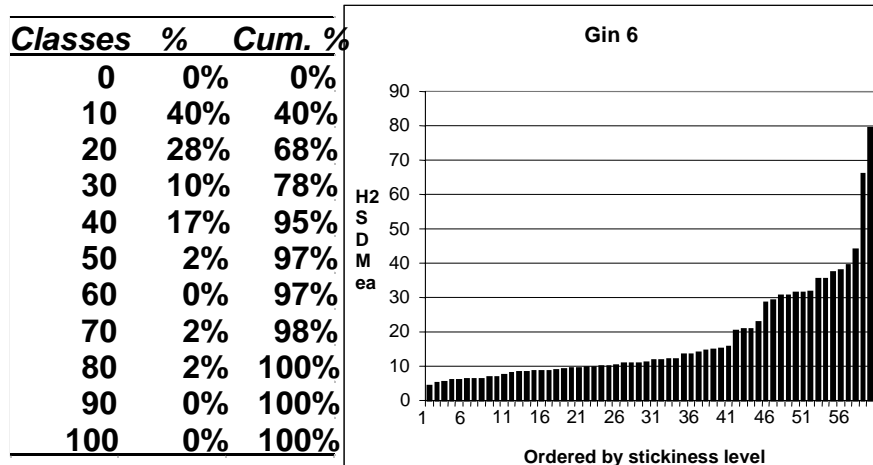


Figure B-34: Stickiness results: gin 6.

H2SD : Gin 7

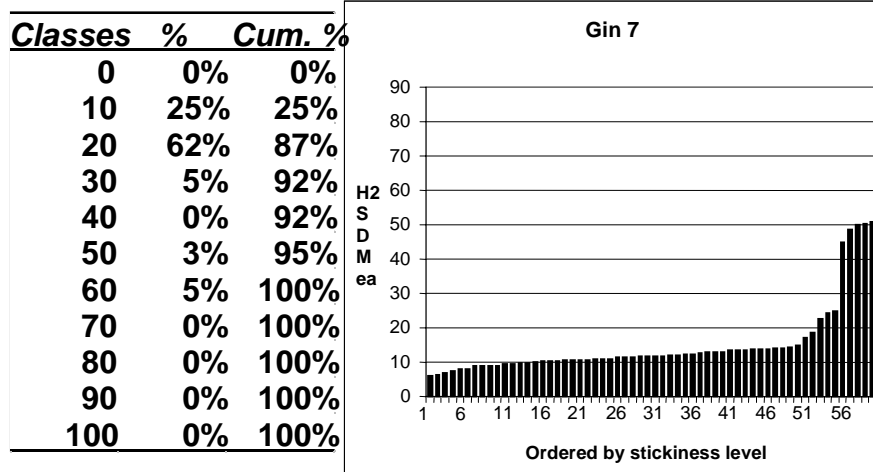


Figure B-35: Stickiness results: gin 7.

H2SD : Gin 8

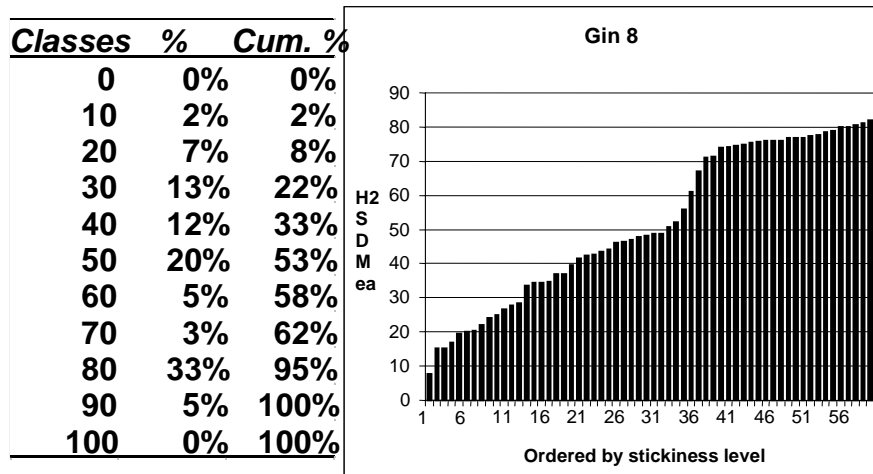


Figure B-36: Stickiness results: gin 8.

H2SD : All Gins

Classes	%	Cum. %
0	0%	0%
10	18%	18%
20	16%	34%
30	6%	39%
40	12%	51%
50	19%	70%
60	14%	84%
70	8%	92%
80	7%	99%
90	1%	100%
100	0%	100%

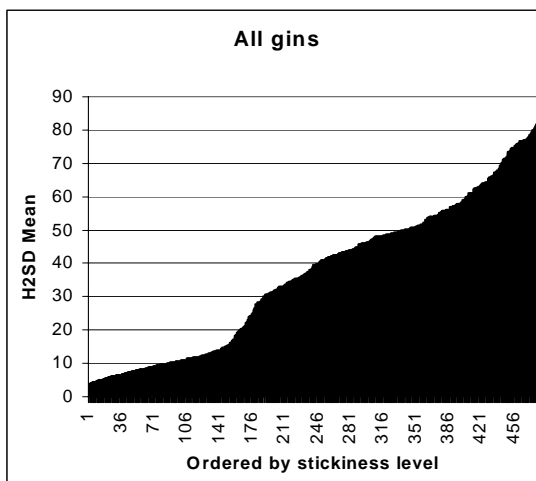


Figure B-37: Stickiness results: all gins.

H2SD : All Gins

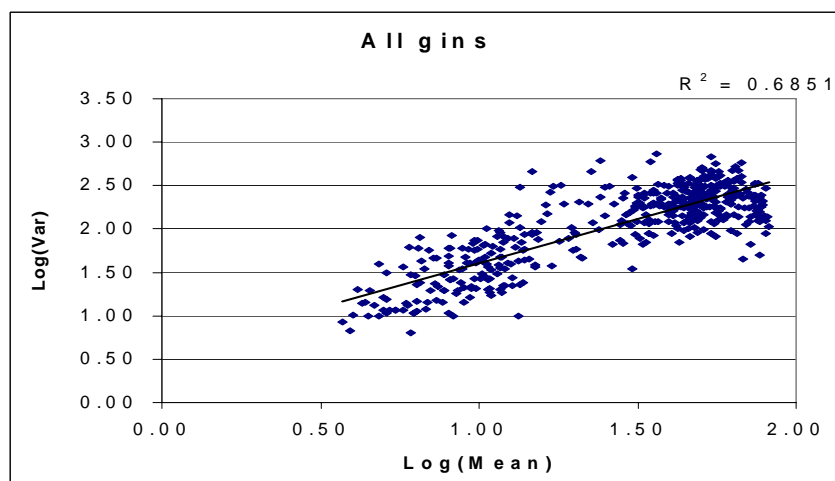


Figure B-38: Log(variance) = f (Log (mean)); all gins.

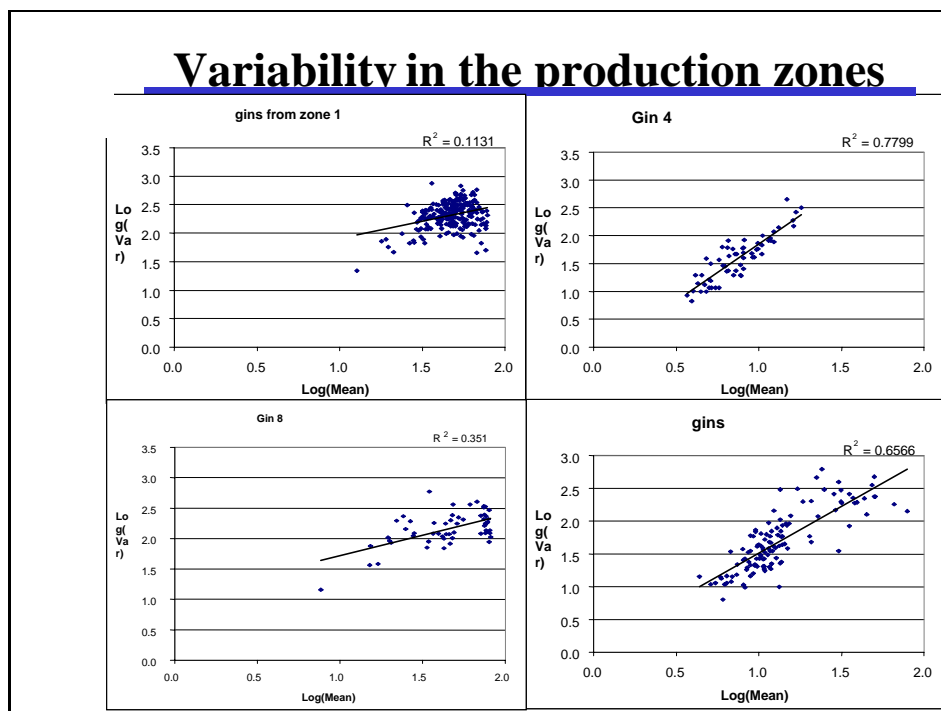


Figure B-39: $\text{Log}(\text{variance}) = f(\text{Log}(\text{mean}))$ per production zone.



Figure B-40: Factory location effect on the H2SD stickiness level.

B.7. The extent and variability of stickiness in the Sudanese 1998 crop using SCT and H2SD devices.

B.7.1. Objective

An evaluation is required of the stickiness potential of Sudanese production along with an estimate of the proportion of the cotton which could be marketed as non-sticky. This evaluation was made using SCT purchased for that purpose, and confirmed by an independent laboratory.

B.7.2. Materials and methods

Five per cent of the bales produced in the 1998-1999 cotton crop were sampled for stickiness measurements.

Several blocks were selected in every gin factory. A block corresponds to a set of 100 bales produced successively. A sample was taken every 20 bales in each block. All the samples were tested in the ARC laboratory using SCT. An independent laboratory, Cotton Incorporated in USA, received 2300 samples for re-testing. Since SCT analysis was too time consuming, this re-testing was performed on CI's H2SD. Only the confirmed data is shown hereafter.

These samples were re-tested in a randomized order to avoid possible drift in the measurement could affect the variability estimations between gin factories. Samples were sorted in accordance with this randomization, but the machine was sent to Montpellier and the samples repacked in boxes in an approximate order compared to the randomization order. As the order of packing the samples was done without taking care of their origin (gin), the final order of testing can be considered as independent of the studied variations factors. In consequence, samples analysis are considered as randomized. Since a randomization of such number of samples in an experiment is a huge work, we take the assumption that samples were randomized for testing on SCT in ARC laboratory.

Internal Cirad reference cottons were analyzed at regular intervals among the Sudanese samples to check the machine response against time.

B.7.3. Results

B.7.3.1. Frequency distribution of the counts

No repetition was available within each bale to check the within probability distribution. Taking care of previous research work on SCT as well as H2SD measurements, a square root transformation was applied before regressions and variance analysis, to approximately stabilize the variance of the measurement error.

Probability distributions of the SCT and H2SD were separately described for each gin factory, using histograms, empirical cumulative distribution charts, moments and quantiles. Distributions of SCT measurements are always asymmetrical to the left, of more pronounced manner for some gins than for others (Annex B-1). Distributions of H2SD measurements are more symmetrical, and we observe the same symmetry difference between gin factories as for SCT (Annex B-2). In one gin, distribution is almost symmetrical. For 3 out of the 4 gin factories, extremes of the distributions are approximately the same for SCT and H2SD. For an other gin on the contrary, SCT measurements spread from 0 to 235, while H2SD measurements spread from 0 to only 128.

Average stickiness clearly varies from gin to another gin (Annex B-1 and Annex B-2). With

SCT, bales from one gin have an average of 8.5, and 31, 39 and 34 sticky points for the other gin factories. (Annex B-3). With H2SD, the same gin also shows the least stickiness with 16 points, the one from the other gins being 39, 44 and 45 sticky points. However, among these 3 gins, one gin seems the most sticky with H2SD and the least with SCT. Differences between gins are significant (Annex B-4 to Annex B-6).

From a practical standpoint, **IF** we arbitrarily fix a threshold of 10 H2SD sticky points to get a moderate stickiness and 20 H2SD sticky points for a sticky cotton, only one gin gives an interesting percentage of non-sticky bales (Table B-3). It is however very important to notice that the representativity of the collected samples is unknown.

Table B-3: Number of samples per gin and stickiness grade.

	H2SD			All
	Non-sticky	Moderate	Sticky	
Gin 1	172	93	115	380
Gin 2	19	16	131	166
Gin 3	5	16	120	141
Gin 4	77	137	671	885

B.7.3.2. Variability between measurements in a same bloc

With SCT or H2SD, a precise measurement can only be reached with several repetitions. Thus, a classification process using a single measurement is automatically severe if a litigation risk has to be limited (Tamime, Gozé et al, 2000). However, taking in account the production process, it is possible that the bales from a single bloc which are produced altogether, could have nearer stickiness potentials than bales that are produced on different days intervals. If this would be true, man take in account the within-bloc variability to propose a more powerful classification operating method.

A variance analysis with one factor shows a highly significant bloc effect, on SCT as well as H2SD. Thus the within-bloc variability is lower than the within-gin variability for stickiness.

A mixed model allows the within and between bloc variance estimation. A likelihood test shows that these variances are not the same depending on the gin. In the square root scale, the different variances estimations are given in Table B-4.

Table B-4: Variance estimations of SCT and H2SD results (square root transformation) depending on the gin.

Factory	Within blocks variance		Between blocks variance	
	\sqrt{SCT}	$\sqrt{H2SD}$	\sqrt{SCT}	$\sqrt{H2SD}$
Gin 1	1.3356	1.2810	1.4366	1.9137
Gin 2	0.9010	1.6202	2.4427	2.4921
Gin 3	3.9971	1.8179	2.1991	1.6601
Gin 4	5.8112	3.5244	1.6997	1.8412

B.7.3.3. Relationship between SCT and H2SD measurements

SCT and H2SD work on almost the same thermodetection principle, but they are different devices working with sample size, sample mass, ..., and temperature that are different. Thus, they generally do not give similar results, but statistic links exist between their results (Frydrych, 1996). The objective of this paragraph is to check the relationship between the results of these devices.

As said earlier, SCT as well as H2SD results were transformed to stabilize their variances through a square root transformation, rendering feasible the regressions calculations.

Relationship between SCT and H2SD is highly significant ($p < 0.01$) using the all set of data, but somewhat loose ($R^2 = 0.29$, annex 3). As the ranking of the gins are not the same for the 2 devices, we checked the effect 'gin' in the regression SCT vs H2SD. Thus in annex 4, we checked the gin effect and the gin x H2SD interaction in a linear model of SCT:

$$Sct = f(gin) + H2sd . g (gin)$$

(Equation B-10)

These tests shows that the regression slope is affected by the gin. Thus we calculated the regression for every gin (annexes 5a to 5d). On bales from gin 3, the slope is not significantly different from 0, and there is no significant relation between SCT and H2SD. By the contrary, the other 3 gins show a relationship between SCT and H2SD, with a low R^2 between 0.17 and 0.28. If we take care of the relation $\text{Sqr}(\text{SCT})$ as a function of $\text{Sqr}(\text{H2SD})$ on the blocks where all 5 samples were present, the coefficient of correlation is $r = 0.70$ (Figure B-41).

These results indicate that the quality of the sampling procedure and of the randomization has a great effect on the relation between SCT and H2SD. Strict sampling procedure has to be performed in order to get a reliable stickiness measurement, as it is done in some countries to perform HVI testing and classification.

B.7.3.4. Contamination from sample to sample on H2SD

Here the question is: is there any contamination from sample to sample in H2SD which can affects the machine reading ? Indeed, it would be possible that some sticky fibers from a previous sample could be transferred to the following non-sticky cotton and thus affects its result.

The method used to detect such effect consists in studying the linear regression which exists between the number of sticky points for the non-sticky reference cotton as a function the number of sticky points of the preceding cotton. It exists a significant relationship ($P = 0.0014$), but it is very loose ($R^2 = 0.0063$) based on square root transformed data.

$$Y = 1.0099 + 0.0804 X$$

In this formula, the constant represents the noise (1 sticky point), while the slopes gives the dependency relation. We have to take care that this regression line is based on results on the X axis are variable as those on the Y axis.

If we forget this limitation, a cotton having 100 sticky points will increase the results on the following non-sticky cotton sample by 10×0.08 , or 0.8 in square value scale. That becomes, in the normal scale, $1 + 1.6 + 0.64$ or 3.24 sticky points, which corresponds to an increase of 2.24 points in average.

If we do not forget this limitation, and according to Snedecor and Cochran, it is possible to correct the slope following a specific statistical method to obtain the following formula which is also significant with a loose R^2 :

$$Y = 1,05 + 0.089 X'$$

Thus would it be necessary to correct the data ?

It is thus significant, and a moderate bias may exist onto the results on a cotton following a highly sticky cotton. However, its consequence is not too important, since it increases the risk of classifying a non-sticky bale as sticky which render the H2SD tests more reliable as it could be expected. We can add that this bias decreases if more than one replication is made for each cotton sample since such contamination will concern mainly the first replication of the measurement.

This represents a financial loss on the producer side, but it improves confidence in the measurements itself and in the cotton producer.

B.7.4. Discussion:

The absence of relation between SCT and H2SD is troublesome for the gin 3 results (SCT and H2SD). Results were all obtained in the same conditions, during a same set of analysis where the order of the samples analysis were randomized. Thus, if these results are valid for 3 gins, they also should be valid for the 4th one. We envisage a mistake in the sample identification for the gin 3.

Among the 4 concerned gins in this experiment, only gin 1 give an interesting part of non-sticky cotton. It is important to notice that the representativity of the Sudanese cotton crop cannot be asserted. However, these results confirm the previous results we have for an earlier crop (see paragraph **B.4.2**), and can be explained the non-coincidence between insect presence in the field and the boll opening phase for one variety.

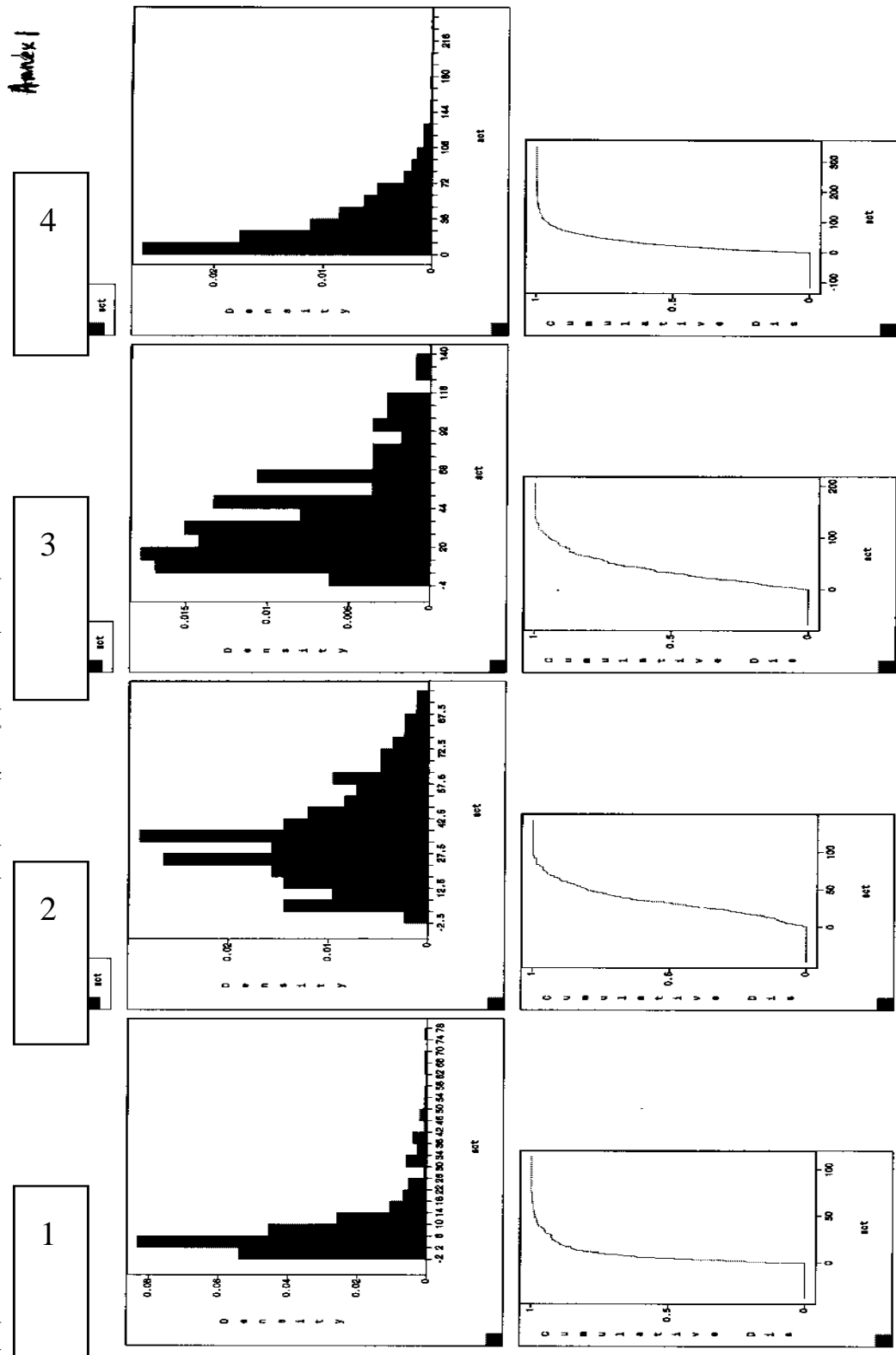
B.7.5. Conclusion: Practical recommendations for cotton classification

Among the gins taken in account in this experiment, gin 1 appears to be the most concerned by a valorization effort: with the same number of bales produced, this gin furnishes the highest number of non-sticky cottons. More generally, strategies should be adopted to concentrate classification efforts depending on short / long term objectives based on economical basis.

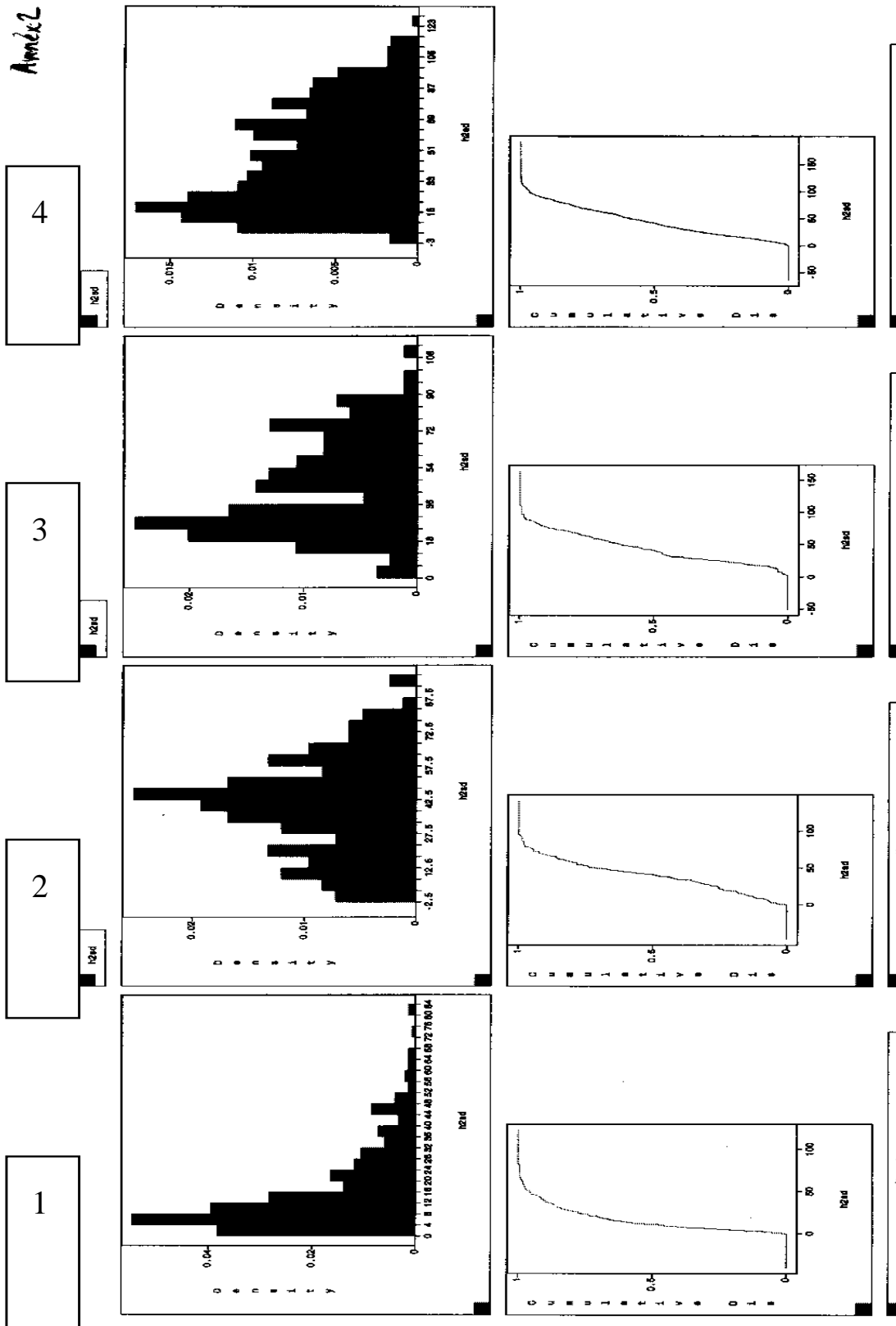
Concerning the utilization of a lower within-bloc variability, a finer analysis of the routine data should provide a more economical procedure to classify cottons. At this point, the within-bloc variance being variable from gin to gin, no general rule can be found. The principle of using tables to evaluate litigation risk can be envisaged to deduce the rules to follow during the classification process in order to get a better return on investment for such a tool.

Strict sampling procedure are necessary to provide reliable information about stickiness at all the different levels in the production (within-bale, within-lot and between lots, ...)

Annex B-1



Annex B-2



Annex B-3

Annex 3

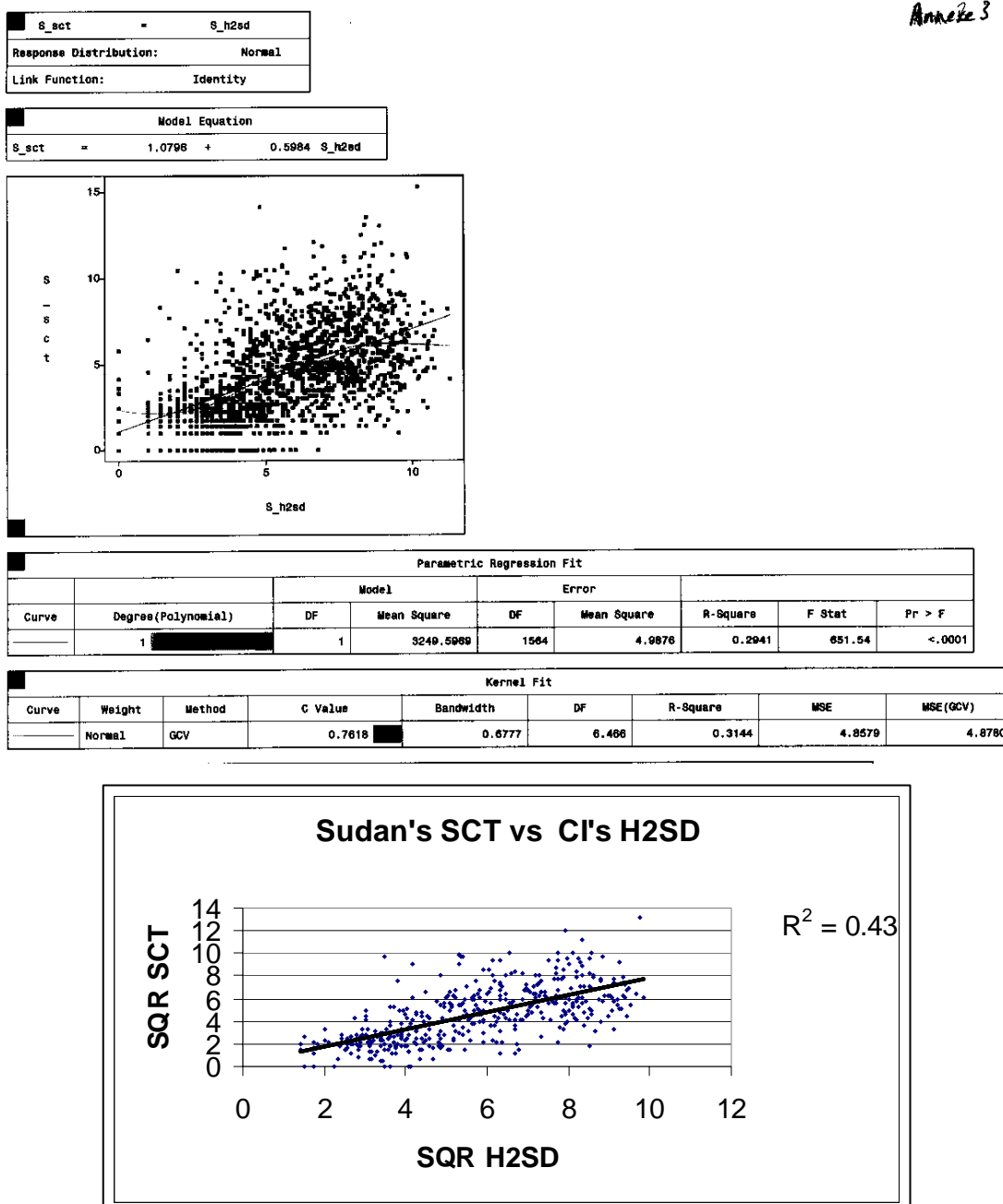


Figure B-41: Comparison of SCT and H2SD results where all measurements are available ($r=0.70$).

Annex B-4

Annex 4.

s_sct	=	s_h2sd	Location	s_h2sd*Location
Response Distribution:		Normal		
Link Function:		Identity		

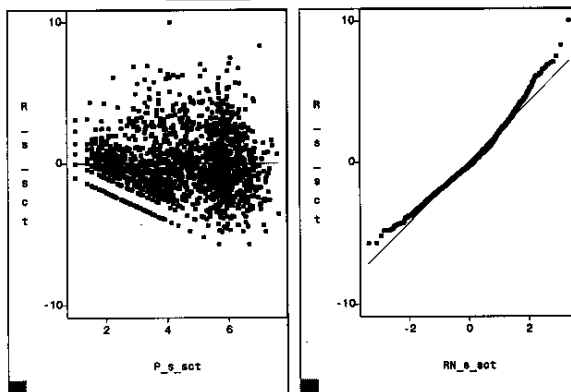
Parameter Information			Nominal Variable Information	
Parameter	Variable	Location	Level	Location
1	Intercept		1	Bagler
2	s_h2sd		2	Haifa
3	Location		3	Massahissa
4			4	Maringen
5				
6				
7	s_h2sd*Location			
8				
9				
10				

Summary of Fit			
Mean of Response	4.4523	R-Square	0.3591
Root MSE	2.1333	Adj R-Sq	0.3562

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Stat	Pr > F
Model	7	3977.5785	568.2255	124.66	<.0001
Error	1580	7099.3016	4.5508		
C Total	1587	11076.8802			

Type III Tests					
Source	DF	Sum of Squares	Mean Square	F Stat	Pr > F
s_h2sd	1	494.5035	494.5035	106.66	<.0001
Location	3	166.7173	62.2391	13.66	<.0001
s_h2sd*Location	3	102.3965	34.1322	7.60	<.0001

Parameter Estimates								
Variable	Location	DF	Estimate	Std Error	t Stat	Pr > t	Tolerance	Var Inflation
Intercept		1	1.4717	0.2106	6.99	<.0001	.	0
s_h2sd		1	0.5449	0.0313	17.41	<.0001	0.5119	1.9533
Location		1	-0.4804	0.3248	-1.48	0.1394	0.1501	6.6634
		1	1.2045	0.5610	2.15	0.0319	0.0974	10.2630
		1	3.6661	0.6796	5.42	<.0001	0.0768	13.0229
		0	0					
s_h2sd*Location		1	-0.1578	0.0689	-2.29	0.0222	0.1994	5.1694
		1	-0.0584	0.0883	-0.66	0.5085	0.0980	10.2043
		1	-0.4525	0.1021	-4.43	<.0001	0.0764	13.0616
		0	0					



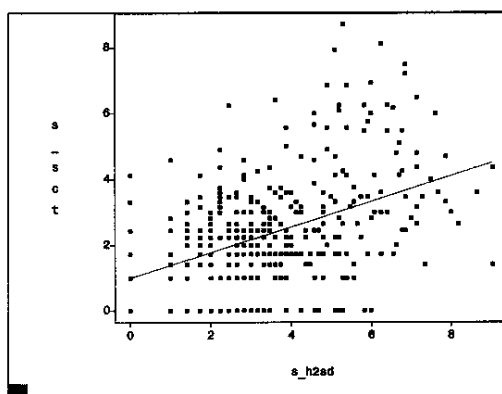
Annex B-5

Annex Sa

Location = Bagier

s_sct	=	s_h2sd
Response Distribution:		Normal
Link Function:		Identity

Model Equation		
s_sct	=	0.9913 + 0.3871 s_h2sd

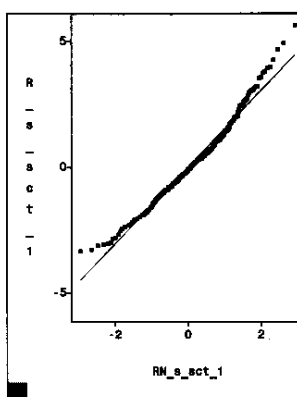
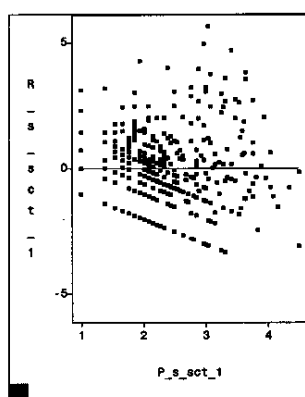


Parametric Regression Fit								
Curve	Degree(Polynomial)	DF	Mean Square	DF	Mean Square	R-Square	F Stat	Pr > F
	1	1	180.8076	377	2.3275	0.1708	77.68	<.0001

Summary of Fit			
Mean of Response	2.3888	R-Square	0.1708
Root MSE	1.5256	Adj R-Sq	0.1687

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Stat	Pr > F
Model	1	180.8076	180.8076	77.68	<.0001
Error	377	877.4771	2.3275		
Total	378	1058.2847			

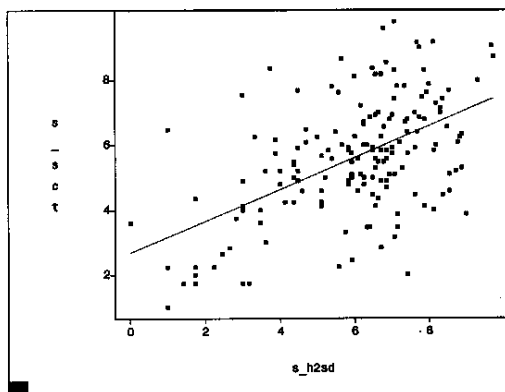
Parameter Estimates							
Variable	DF	Estimate	Std Error	t Stat	Pr > t	Tolerance	Var Inflation
Intercept	1	0.9913	0.1769	5.61	<.0001		0
s_h2sd	1	0.3871	0.0439	8.81	<.0001	1.0000	1.0000



Location = Halfa

s_sct = s_h2sd
Response Distribution: Normal
Link Function: Identity

Model Equation
s_sct = 2.6762 + 0.4865 s_h2sd

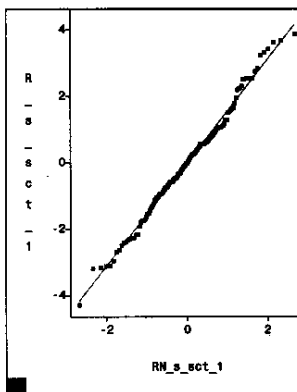
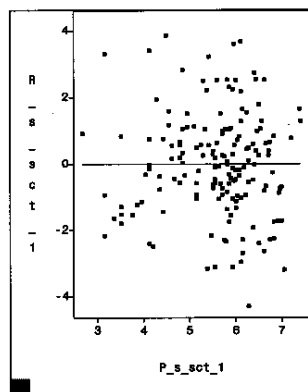


Parametric Regression Fit						
Curve	Degree(Polynomial)	Model		Error		Pr > F
		DF	Mean Square	DF	Mean Square	
-----	1	1	158.0935	164	2.4282	0.2842
						65.11
						<.0001

Summary of Fit			
Mean of Response	5.5811	R-Square	0.2842
Root MSE	1.5593	Adj R-Sq	0.2798

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Stat	Pr > F
Model	1	158.0935	158.0935	65.11	<.0001
Error	164	398.2281	2.4282		
Total	165	556.3217			

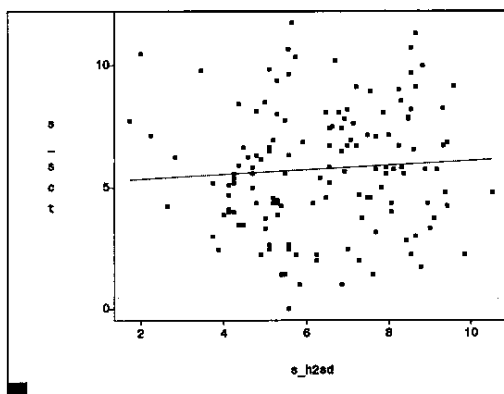
Parameter Estimates							
Variable	DF	Estimate	Std Error	t Stat	Pr > t	Tolerance	Var Inflation
Intercept	1	2.6762	0.3798	7.05	<.0001	.	0
s_h2sd	1	0.4865	0.0603	8.07	<.0001	1.0000	1.0000



Location = Haasshiassa

s_sct = s_h2ed
Response Distribution: Normal
Link Function: Identity

Model Equation
s_sct = 5.1578 + 0.0924 s_h2ed

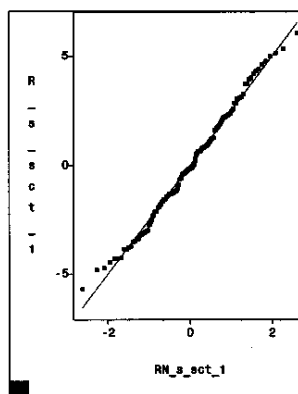
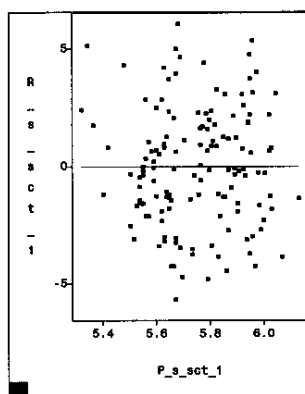


Parametric Regression Fit								
Curve	Degree(Polynomial)	Model		Error		R-Square	F Stat	Pr > F
		DF	Mean Square	DF	Mean Square			
1	1	1	4.1141	139	6.2476	0.0047	0.68	0.4185

Summary of Fit			
Mean of Response	5.7479	R-Square	0.0047
Root MSE	2.4995	Adj R-Sq	0

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Stat	Pr > F
Model	1	4.1141	4.1141	0.68	0.4185
Error	139	868.4169	6.2476		
Total	140	872.5310			

Parameter Estimates							
Variable	DF	Estimate	Std Error	t Stat	Pr > t	Tolerance	Var Inflation
Intercept	1	5.1578	0.7571	6.81	<.0001	.	0
s_h2ed	1	0.0924	0.1139	0.81	0.4185	1.0000	1.0000

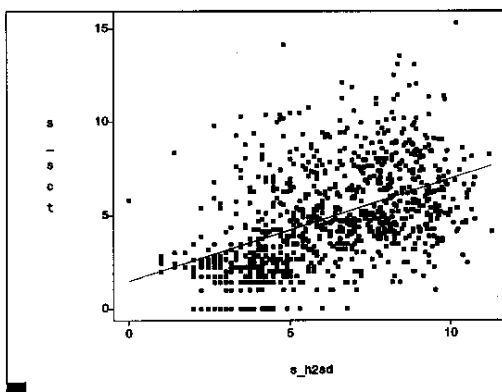


Location = Marangan

Annex Sd

s_sct	=	s_h2ed
Response Distribution:	Normal	
Link Function:	Identity	

Model Equation		
s_sct	=	1.4717 + 0.5449 s_h2ed

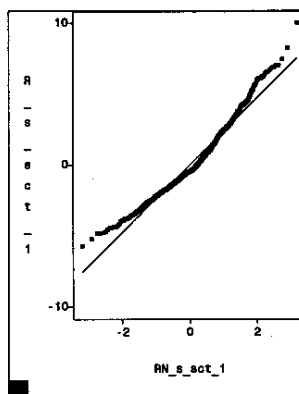
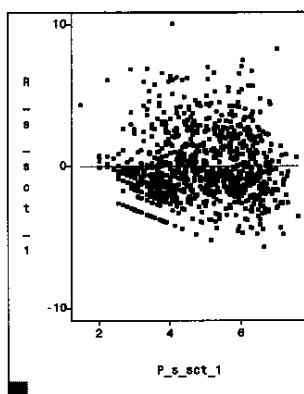


Parametric Regression Fit								
Curve	Degree(Polynomial)	Model		Error		R-Square	F Stat	Pr > F
		DF	Mean Square	DF	Mean Square			
	1	1	1380.1411	880	5.6308	0.2178	245.10	<.0001

Summary of Fit			
Mean of Response	4.9194	R-Square	0.2178
Root MSE	2.3729	Adj R-Sq	0.2170

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Stat	Pr > F
Model	1	1380.1411	1380.1411	245.10	<.0001
Error	880	4955.1796	5.6308		
Total	881	6335.3207			

Parameter Estimates							
Variable	DF	Estimate	Std Error	t Stat	Pr > t	Tolerance	Var Inflation
Intercept	1	1.4717	0.2343	6.28	<.0001	.	0
s_h2ed	1	0.5449	0.0348	15.66	<.0001	1.0000	1.0000



Annex B-6

Annex 6

The SAS System

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The GLM Procedure

Class Level Information

Class	Levels	Values
Location	4	1 2 3 4
block1	460	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 158 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217 218 219 220 221 222 223 224 225 226 227 228 229 230 231 232 233 234 235 236 237 238 239 240 241 242 243 244 245 246 247 248 249 250 251 252 253 254 255 256 257 258 259 260 261 262 263 264 265 266 267 268 269 270 271 272 273 274 275 276 277 278 279 280 281 282 283 284 285 286 287 288 289 290 291 292 293 294 295 296 297 298 299 300 301 302 303 304 305 306 307 308 309 310 311 312 313 314 315 316 317 318 319 320 321 322 323 324 325 326 327 328 329 330 331 332 333 334 335 336 337 338 339 340 341 342 343 344 345 346 347 348 349 350 351 352 353 354 355 356 357 358 359 360 361 362 363 364 365 366 367 368 369 370 371 372 373 374 375 376 377 378 379 380 381 382 383 384 385 386 387 388 389 390 391 392 393 394 395 396 397 398 399 400 401 402 403 404 405 406 407 408 409 410 411 412 413 414 415 416 417 418 419 420 421 422 423 424 425 426 427 428 429 430 431 432 433 434 435 436 437 438 439 440 441 442 443 444 445 446 447 448 449 450 451 452 453 454 455 456 457 458 459 460

Number of observations 2300

Dependent Variables With
Equivalent Missing Value Patterns

Pattern	Obs	Dependent Variables
1	1568	s_sct
2	1572	s_h2sd

The SAS System

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The GLM Procedure

NOTE: Variables in each group are consistent with respect to the presence or absence of missing values.

The GLM Procedure

Dependent Variable: s_sct

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	446	9099.80033	20.40314	11.57	<.0001
Error	1121	1977.07990	1.76368		
Corrected Total	1567	11076.88023			

R-Square	Coeff Var	Root MSE	s_sct Mean
0.821513	29.82820	1.328034	4.452278

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Location	3	2254.422133	751.474044	426.08	<.0001
block1(Location)	443	6845.378194	15.452321	8.76	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Location	3	1951.259839	650.419946	368.79	<.0001
block1(Location)	443	6845.378194	15.452321	8.76	<.0001

The GLM Procedure

Dependent Variable: s_h2sd

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	446	6952.850589	15.589351	8.20	<.0001
Error	1125	2140.032215	1.902251		
Corrected Total	1571	9092.882804			

R-Square	Coeff Var	Root MSE	s_h2sd Mean
0.764648	24.46885	1.379221	5.637147

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Location	3	2073.860520	691.286840	363.40	<.0001
block1(Location)	443	4878.990069	11.013522	5.79	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Location	3	1649.578023	549.858674	289.06	<.0001
block1(Location)	443	4878.990069	11.013522	5.79	<.0001

B.8. General conclusions for component A

The objective of this component was to find a way to estimate the stickiness potential of cotton fibers, its variability at different levels (bale, lot, ...), to devise a sampling procedure and to define a procedure for a complete annual crop production classification.

As planned in the Appraisal Report, which constitutes an agreement for funding by the International Cotton Advisory Committee and the Common Fund for Commodities, some of the tools available were tested during this project on Sudanese cotton production.

At the beginning of the project, two main measuring tools were used to characterize the stickiness potential of cotton fiber samples and to which we added extra experiments to determine the feasibility of their use:

- The Stickiness Cotton Thermodetector (SCT) was first used at the beginning of the project. It is important to note that at the time this project was agreed, SCT was the 'state of the art' device to measure stickiness, as the machine was the stickiness measuring method recommended by the International Textile Manufacturers Federation (1994). At that time, new developments were ongoing to design other methodologies, but they were not taken into account or used in this project since they were not completed.
- High Performance Liquid Chromatography (HPLC) was used in parallel to assay all individual sugars contained in the 'sticky deposit' of some samples. This method was only used for "Component b".
- In 1998, however, it was decided to move on by using a newly developed measuring technique called High Speed Stickiness Detector (H2SD) because SCT is too time consuming in classification procedures. Some characteristics were described to demonstrate its advantages, and results during this project contributed to its improvement and to defining its advantages compared to SCT technique.

Standard texts exist to describe the operating procedures for taking samples and the operating procedure for the two commercial measuring devices mainly used in this project. Once again, it is important to note that the enclosed standard documents are drafts which cannot be used as it is. Reference to official documents should be made if these techniques are to be used.

Even if these standards are on their way to being adopted (after some further modifications), we have already noted that they may or may not be used in normal commercial testing, especially concerning the sampling procedures, without taking care of the variability of stickiness at different levels of the production (i.e. within bale, within lot, ...). The studies reported here focused primarily on evaluating this within-bale variability. With that knowledge, it is then possible to devise the operational conditions of classification (number of samples per bale or lot and / or the number of measurements per sample) to insure the 'certification' of the stickiness level determination for each lot taking care of the litigation risk between a seller and a purchaser for these raw materials. Thus a low level of complaints could be expected.

Many experiments were designed with such an idea in mind. The first one was based on the SCT's that were installed at the beginning of the project in the Agricultural Research Corporation laboratory in Wad Medani. After a training of all the personnel, six technicians run the six installed SCTs to prepare the aluminum foils. These foils were then transmitted to two other persons who are in charge of counting the sticky points that stuck to the foils.

Based on a large sampling (one sample from 16 layers from 500 bales coming from roller gin plants and 500 from saw gin plants), this experiment showed that the distribution of the sticky

points does not follow the typical Poisson statistical law which was expected. Moreover, the stickiness is not homogeneously distributed within the bales.

This specific distribution of the SCT sticky points was mainly due to an operator effect and to an interaction between the counter effect and the real stickiness level of each bale. In other words, the stickiness level labeled to a given bale is dependent on who counts the sticky points, and the real stickiness level of that given bale. Some independent experiments confirmed this hypothesis.

In these conditions, it is not possible to evaluate stickiness (as well as any other characteristics) since results can be biased at anytime, and this bias is not acceptable in a commercial use due to the important risk of complaints it could induce. In complement, we were not able to deduce a simple statistical law from the collected data, rendering impossible the establishment of a specific operating procedure for a classification process.

At that point, it was decided to give up SCT as a tool for such a type of classification process since it introduces an operator effect. However, it is important to note that SCT is able to separate bales having different stickiness level but only at a laboratory scale.

We decided to begin to use H2SD to characterize 100 bales because its automation induces no operator effect and no interaction in the measurement. One hundred other bales were analyzed with H2SD to achieve the goal of finding a statistical law for the sticky points repartition in the bales. An hypothesis concerning the statistical within-bale distribution law of the stickiness was brought based on the analysis of these bales: it would be a negative binomial distribution with shape factor $k = 9,43$.

Based on this assumption, this report described a method for calculating litigation risk from the probability distribution of sticky point measurements, and the method employed was illustrated using the results concerning within-bale variability. It was shown that a single classification threshold would lead to a maximum litigation risk equal to 25%. Thus the application of a classification threshold (producer side) lower than an evaluation threshold (buyer side) was recommended to lower the maximum litigation risk. Some table were designed to estimate the risk of litigation depending on the two different thresholds that are fixed in the commercial procedure. It should be remembered that a specific organization of the production could have a large effect on the within-bale distribution for stickiness, and could somewhat affect the way of isolating sticky bales from non-sticky bales.

To confirm this hypothesis, an extra experimentation was planed to study the within-bale distribution of the Sudanese production with respect to the geographical representativity of the gins and the proportion of the two main grown varieties, Acala and Barakat. A specific sampling procedure was designed to represent the Sudanese production. The stickiness characterization was made on H2SD measuring device.

The corresponding results demonstrate that a wide range of stickiness can be recorded within Sudan as represented by the gin factory locations assuming that the seed-cotton is collected in their respective surroundings areas. Some areas seem to have greater sensibility to insect infestation, that may be explained by the location and the variety, and their interaction. However, it has also been showed that a part of the Sudanese production IS affected AT A LOW DEGREE by stickiness. In average, the within-bale stickiness variability remains non-significant, i.e. there was no difference of stickiness reading depending on the layer in which a sample was taken in the bale.

Among the gins taken into account in this experiment, some appear to be the most concerned by a classification effort: with the same number of bales produced, these gins furnish the

highest number of non-sticky cottons. More generally, this conclusion leads to find strategies to concentrate classification efforts depending on short / long term objectives based on economical basis.

Some information can be deduced from this data in order to elaborate an organization for the collection and the ginning of seed-cotton based on blocks in place of grouping bags from different blocks. We already can see that such a classification for stickiness in these production conditions could bring another use of the measurement results. This information, collected in such a production organization (no grouping of seed cotton coming from different production zones + classification process) would allow a better knowledge about the production areas. Indeed, when seed cotton from one single block is ginned separately, any stickiness problem is mainly related to its origins, i.e. the production block. With such an information, a map can be drawn to locate the major locations where insect stickiness appears, and thus researches of its cause(s) could be implemented. This map could be used in relation with pest infestations ones to deduce varietal sensitivities where some varieties could escape from the insect infestation peak, soils effects, ... or other interaction with production methodologies. The early picking also appears to be the most effective solution as deduced from discussion in Wad Medani end of 2000. However, this will require appliance of different combined solutions to fit against stickiness.

From the previous experiment, we pointed out that a specific organization of both the production, the collection of seed-cotton, its ginning and its classification could permit to improve the stickiness situation of the Sudanese production. However, the actual condition has to be also considered to devise the operating methods and the sampling conditions for the classification process.

Concerning the utilization of a lower within-bloc variability, a finer analysis of the routine data should provide a more economical procedure to classify cottons. At this point, the within-block variance being variable from gin to gin, no general rule can be found. The principle of using tables to evaluate litigation risk can be envisaged to deduce the rules to follow during the classification process in order to get a better return on investment for such a tool.

To sum up, it exists a variability of stickiness depending on the variety, the producing blocks that can be partially solved by a proper organization of the seed-cotton collection and ginning practices. A classification process can be implemented at least to know more about some kind of mapping to solve the insect infestation or limit its effect. The other use of the classification would be to warrant a given quality to homogeneous lots in terms of stickiness level. The conditions of testing are not clear since variability of stickiness on the case of the actual organization do not allow to find a statistical law to define precision and accuracy of the measurements which could be valid for the entire country. However, a measurement can be done to isolate highly contaminated lots from the rest of the production, and begin to stabilize an effective organization, and begin to market the fibers based on this measurement.

Method to evaluate the litigation risk depending on two thresholds – at the classification and at the evaluation steps – are now available and could be applied as soon as a statistical law will be deduced from the data after a proper organization of the cotton production. From these numerous experiments, we learned that SCT is not fully adapted for a classification process since a human effect occurs during the measurement that remove part of the confidence we can make in the results during a classification process. Thanks to its automation, H2SD has not this bias and could be used for a classification process as it brings no human factors interacting with the measurement.

COMPONENT B

Development of a threshold for the economical processing of sticky cotton

Chapter C. Component B: Development of a threshold for the economical processing of sticky cotton

Methods for neutralizing stickiness are under development at CIRAD. The laboratory work carried out so far has indicated that stickiness may be largely neutralized without affecting the quality of the cotton. Employing a neutralizing process requires additional time and cost and should only be used if financially advantageous. Establishment of thresholds for spinning sticky cotton will therefore be of a major advantage to the spinning industry. The main focus of this component is to establish such a threshold.

The operations envisaged in this component will take place in France at Institut Textile de France, where, in close consultation with CIRAD, research activities will focus on the impact of varying degrees of stickiness on the spinning process (at factory scale) and the variables that affect this impact. Sticky cottons disrupt the spinning process by sticking to various parts of the spinning machines. The problem varies depending on the stage of the process leading to the production of the yarn. Cotton fiber preparation (beating, mixing, opening, cleaning) is affected greatly if the quantity of sticky cotton involved is very large (several hundred kilograms). Stickiness has a considerable effect during carding and leads to irregularities in card slivers or, in extreme cases, renders carding impossible. The machines must then be stopped and cleaned. As far as the drawing frames, brush frames and spinning machines are concerned, the honeydew is deposited onto the rollers (feed, draw, etc.) and causes yarn irregularities and breakages. Rotor spinning suffers from problems such as the frequent fouling of the feed tables and rotors, which requires machines to be stopped repeatedly and cleaned. The result is lower yarn quality and higher production costs.

Activities related to developing post-ginning measures as foreseen in the project will be largely based on experience gained by CIRAD in earlier work on the neutralization of stickiness in cotton (in particular the impact of pressure, heat and humidity, as studied and applied under laboratory conditions). Research that made use of the SCT-Thermodetector has revealed that the number of sticky points in the test samples fluctuates depending on the relative humidity of the ambient air. Results in the 55% to 65% range seem to be stable. Outside this range there is a marked fall in the number of sticky points. The maximum sticky potential is therefore expressed between 55 and 65% relative humidity. This points to 2 ways of neutralizing stickiness: drying or humidification. The so-called TNCC9 of neutralizing stickiness developed by CIRAD uses the same combination of factors as the thermodetector, i.e. pressure, heat, humidity. A brief description of this method is given in Appendix V. The results have shown the importance of studying the impact of stickiness in a real-scale environment.

The studies to be undertaken in the framework of the project will determine the effects of sticky cotton on the spinning process and on the quality of the yarn and the resulting product. The threshold level of sticky cotton that will still yield end-products of acceptable quality will be established. Tests will also be undertaken to assess to what extent sticky cotton can be blended with non-sticky cotton to obtain an acceptable level of quality, i.e. allow spinning without disrupting the regular spinning process. The tests will differentiate between conventional (ring) and rotor spinning, and will be performed different under atmospheric conditions in order to establish the impact of different moisture and temperature levels. All tests will be performed under industrial conditions and will use the lint from 60 bales classified as to degree of stickiness in component (a) (approximately 13,500 kg). Quality tests will be undertaken in the ITF and CIRAD laboratories using certified measuring equipment and standard procedures for the establishment of the properties/deficiencies to be determined.

In the framework of this component, the following outputs will be produced through undertaking the described activities.

Output 2.1 The effects of sticky cotton on the spinning process and quality of the yarn or resulting product.

About 400 kg of each cotton (about 2 bales) will be required from preparation to drawing. 100 kg of lint will be sufficient for the spinning process. All tests (on 30 x 2 bales) will be performed under industrial conditions. Breakages at different steps in the process will be counted and the production process will be evaluated through spinning. Laboratory tests will consist of measuring:

- fiber length and strength characteristics on an HVI Zellweger-Uster line (on raw fiber and card sliver), and maturity and fineness on a Shirley Maturity Meter;
- level of stickiness using an SCT sticky cotton detector at each step in production from bale to the second drawing, to evaluate any variations in the course of the production process;
- regularity at each step in the production process (card sliver to yarn) using an Uster Tester II regularimeter, and the strength of the yarn produced (Super web apparatus);
- Classimat, to classify the different defects (Uster, Classimat II);

The level of stickiness during spinning will be evaluated by qualitative analysis of stickiness during different steps in the production process and by the quantitative analysis of the laboratory tests in comparison with non sticky cottons.

The same cotton batches will be used in rotor spinning. The controls performed during the production process and the laboratory tests carried out will be the same as for the conventional spinning process. The quality of the yarn from the resulting product will be determined by making use of the method (developed by the Cotton Technology Laboratory of CIRAD-CA) that differentiates between neps according to their different origins: seed coat fragments, fiber neps, sticky neps and stem or leaf fragment neps. This method will be used to count the number of neps induced by stickiness in the industrial yarn and consists of regularimetry tests performed on a Uster UT3 regularimeter. The settings chosen will be as follows: speed 50m/mn, thin (-50%), thick (+50%), neps (200%). These settings will be used for the two regularimeter tests, i.e. normal test (for the total number of neps) and detailed analysis which will be performed to identify the different neps observed. Each imperfection is examined in detail using a magnifying glass and strong lighting. The yarn is stopped over a given period of time (20 seconds), then is loosened in order to stabilize for 5 seconds before the reading. Imperfections will be classified as seed coat fragments, fiber neps (entangled fibers and sticky neps) and fragments such as leaves. Percentages obtained for each type of imperfection will be adjusted to total neps on 1,000 m to obtain the number of neps per type of imperfection over 1,000 m.

Activity 2.1.1 Cotton with known levels of stickiness will be spun on **ring** and **rotor** spinning machines (industrial scale).

Activity 2.1.2 The effects of sticky cotton on the spinning process and resultant yarn quality will be established.

Output 2.2 Establishment of stickiness thresholds for spinning.

Activity 2.2.1 The economically acceptable level of stickiness on ring and rotor spinning machines (industrial scale) will be determined. A level of stickiness that prohibits spinning without prior processing will be established.

Output 2.3 Blends of sticky cotton with non-sticky cotton will be prepared such that stickiness will not be a problem during spinning.

One way of using sticky cottons would be to mix them with non sticky cottons in order to obtain a mix whose stickiness is below the critical spinning threshold. The proportions of each type of cotton would depend upon the potential stickiness of the contaminated cotton which itself depends on at least 2 factors, namely the number of sticky points measured on the sticky cotton detector and the distribution and size of these sticky points. Five types of cotton (among the 30 employed in the industrial spinning tests) will be used (for example with 25, 50, 75, 100 and 150 sticky points). These cottons will be mixed in various proportions with non sticky cotton. The number of sticky points along with their size and distribution will be studied.

Activity 2.3.1 Mixes of cottons from different origins (sticky and non sticky) will be prepared.

Activity 2.3.2 Cotton mixes will be measured on the stickiness detector and standards will be established to help spinners to mix sticky cotton with non-sticky cotton without affecting the spinning process (ring and rotor) or yarn quality.

Output 2.4 The effect of atmospheric moisture on cotton stickiness will be established.

The relative humidity of the air is known to have an effect on the spinning of sticky cottons. Spinners use this property in an empirical manner. The aim of this study is to determine the critical threshold for the relative humidity of the air during spinning cottons of different stickiness levels (number of sticky points and their sizes). Six types of cotton (among the 30 employed in the industrial spinning tests) will be used. The study of the spinning process (micro-spinning) under different relative humidity conditions, will be performed using conventional and rotor spinning techniques for three types of yarn counts. All the disruptions that occur during the yarn production process (carding, drawing, spinning, rotors) will be evaluated (deposit of sticky points on various parts of the machines, yarn winding, yarn breakage, etc.). Yarn strength and regularity will be measured. Different types of neps will be identified, counted and studied.

Activity 2.4.1 The effect of atmospheric humidity on the spinning of sticky cotton and on yarn quality will be established.

This experiment is described below.

C.1. Carded Spinning Of Sticky Cotton: Effect of stickiness on productivity and yarn quality

C.1.1. Introduction

Cottons are rendered sticky by sugars derived primarily from entomological and physiological sources (Frydrych, 1998; Perkins, 1983). The entomological sugars take the form of honeydew produced by insects living on the cotton plant, mainly the aphid *Aphis gossypii* and the white fly *Bemisia tabaci*. The physiological sugars are natural cotton sugars produced as residues after the synthesis of cellulose.

Papers concerning cotton stickiness (Floek, 1998; Frydrych, 1998; Hector, 1989; Hoelscher, 1998; Perkins, 1983; Shigeaki, 1992) clearly describe how machine parts in contact with the fiber are fouled by the stickiness and underline the increase in the breakage incidence during spinning. Substantial productivity losses have been reported. Although numerous such reports have been published, these cannot be used for a quantitative approach to the stickiness phenomenon. Which type of stickiness measurement is the most suitable to predict fiber behavior during spinning ? What is the exact relationship between breakages, efficiency and stickiness ? These questions, and many others required to address the stickiness problem, have yet to be answered with precision. It is therefore difficult to evaluate accurately the economic effects of stickiness on the spinning industry (Floek, 1998) and in consequence it is impossible to determine in a rational manner the discount that should be applied to sticky cottons (Hoelscher, 1998).

To address these questions and gain a more precise understanding of the effects of stickiness in spinning we conducted a quantitative study using a broad range of sticky cottons (Fonteneau-Tamime, 2000). The bales of cotton were spun into yarn on an industrial production line. Different qualitative and quantitative parameters were recorded throughout the processing from bale opening to yarn in order to monitor product quality and machine productivity. Part 1, presented here, considers process productivity. The quality aspects of production are described in part 2.

C.1.2. Materials and Methods

C.1.2.1. Materials

This study of the effects of stickiness in carded spinning involved 26 bales of cotton (*Gossypium hirsutum*).

Sixty bales from the 1996/97 Sudanese cotton crop were available for the study. The ARC (Agriculture Research Corporation), in collaboration with SCC (Sudan Cotton Company), selected these bales on the basis of stickiness measurement using a mini-card test. The two main cultivated varieties were included as well as the two types of ginning used in Sudan (Table C-1).

Table C-1: Distribution of the sticky bales by variety and ginning equipment.

Stickiness level	Acala-roller	Acala-saw	Barakat-roller
Non sticky	2	2	2
Slightly sticky	8	8	8
Moderately sticky	8	8	8
Highly sticky	2	2	2

Acala fibers of medium length were used for the carding spinning experiment, while Barakat fibers were used for the combing spinning study.

About 30 bales were selected from the 60 for the spinning tests. These 30 bales were selected to cover a range of stickiness while keeping the range of the other fiber parameters as tight as possible. A sampling procedure in 10 equidistant layers in each bale, was completed in order to measure their fiber characteristics. The following measurements were made:

- HVI (*High Volume Instrument ZELLWEGER USTER 900*), for Mean Length (ML) and Upper Half ML (UHML), length uniformity UI%, HVI strength and elongation;
- FMT (*Fineness Maturity Tester SDL3*), for micronaire, fineness and maturity;
- SCT (*Thermodetector SCT*), for the number of sticky points;
- H2SD (*High Speed Stickiness Detector*), for the number of sticky points and their sizes.

The first sample (100 g) taken from the top of each of the 30 bales analyzed using all the above machines. The other 9 samples were analyzed on SCT and H2SD to evaluate the within-bale variability of the stickiness and the size distribution of the sticky points.

Ten replicates of the measurements were made for HVI and 3 for FMT, SCT and H2SD.

Twenty-four bales were finally selected for the carded spinning tests. Ten of these were roller ginned. Their characteristics were relatively homogeneous and covered a wide range of stickiness (from some points to 50 sticky points as measured using the H2SD). All of the bales showed some stickiness. Two non-sticky bales from Central Asia were added as references. Carded spinning tests were then performed using 26 bales (10 being roller ginned).

When considering the Barakat bales as references in the combed spinning experiment, they did not cover a sufficiently broad range of stickiness. Insect infestation of this variety during that 96/97 crop was very low. We did not find any bales with more than 13 SCT sticky points. Thus, the number of bales tested in the combed process was reduced to 5. The protocol and results of this experiment will be discussed in paragraph C.3.

C.1.2.2. Fiber quality determination

Fiber quality characteristics are given in

Table C-2, while stickiness data is given in Table C-3.

Table C-2: Fiber quality characteristics for selected bales in the spinning tests.

Bale	Ginning*	Variety	ML	UHML	UI%	Strength	Elong.	IM	MR	PM%	H	HS	Rd%	+B
			Mm	Mm		g/tex	%				mtex	mtex		
AC1	S	-	23.9	28.5	83.7	30.1	5.7	4.6	0.92	81.6	195	212	72.3	10.3
AC2	S	-	23.9	28.8	82.9	29.0	5.6	4.7	0.92	81.3	201	219	69.2	11.1
AR02	R	Acala	23.2	27.7	83.6	27.3	5.0	4.0	0.86	76.5	173	201	73.7	12.4
AR05	R	Acala	22.8	27.4	83.3	27.7	4.8	3.9	0.81	72.4	176	217	72.7	12.8
AR07	R	Acala	20.5	25.5	80.4	25.3	4.7	3.2	0.72	63.5	153	213	74.7	11.5
AR08	R	Acala	22.4	27.1	82.6	28.4	4.7	3.6	0.78	69.9	164	209	73.5	11.9
AR14	R	Acala	21.8	26.6	82.0	26.4	4.5	3.4	0.75	66.2	160	215	71.9	11.7
AR16	R	Acala	21.8	26.6	81.9	27.6	4.6	3.5	0.73	64.9	168	230	73.4	11.5
AR17	R	Acala	22.1	27.0	82.0	26.9	4.7	3.3	0.75	66.6	153	204	72.9	12.0
AR18	R	Acala	21.5	26.2	81.9	26.9	4.5	3.4	0.75	66.2	160	215	73.4	12.1
ARNC1	R	Acala	22.8	27.0	84.4	27.1	5.1	4.0	0.84	75.0	176	209	75.0	9.6
ARNC2	R	Acala	23.1	27.5	83.9	26.6	5.2	3.9	0.81	72.4	176	217	73.7	9.4
AS01	S	Acala	19.9	24.8	80.4	24.7	4.4	3.6	0.77	68.8	163	211	74.5	12.3
AS02	S	Acala	22.0	27.2	80.8	27.9	4.8	3.4	0.80	71.2	153	192	73.2	12.0
AS04	S	Acala	21.5	26.3	81.6	26.4	4.6	3.8	0.82	72.8	166	203	75.2	12.0
AS05	S	Acala	22.0	27.1	81.1	27.9	4.9	3.4	0.80	71.2	153	192	75.0	12.1
AS06	S	Acala	23.2	28.1	82.6	30.7	5.2	3.3	0.75	67.0	151	200	75.5	11.6
AS08	S	Acala	21.0	26.3	80.0	27.5	4.7	3.3	0.77	68.7	152	197	74.0	11.9
AS09	S	Acala	21.2	26.2	81.0	25.8	4.6	3.9	0.74	65.9	187	252	73.8	11.7
AS10	S	Acala	21.2	26.2	80.9	26.9	4.8	3.7	0.78	69.4	168	216	75.2	11.8
AS13	S	Acala	22.2	27.2	81.7	26.4	4.8	3.9	0.78	69.5	179	229	74.3	11.9
AS14	S	Acala	22.5	27.6	81.4	27.6	4.8	3.7	0.79	70.5	165	208	75.4	12.0
AS15	S	Acala	21.6	26.4	81.7	26.4	4.6	4.2	0.82	73.2	188	229	72.6	11.6
AS16	S	Acala	22.0	27.0	81.5	27.3	4.7	3.9	0.79	70.0	178	226	76.4	10.9
AS19	S	Acala	22.2	26.9	82.7	28.2	5.1	3.9	0.82	72.8	177	217	79.6	10.3
AS20	S	Acala	22.4	27.1	82.7	28.1	5.1	4.0	0.81	72.1	184	227	79.1	10.0

* S: Saw ginned R: Roller ginned

Two non-sticky bales were included in the study originated from Central Asia. The remaining 24 corresponded to various varieties of Acala type and had been produced in Sudan in 1996-1997. Ten of these were roller ginned and 14 were saw ginned. The cottons were selected to cover a broad range of stickiness, from non-sticky to very sticky, but with the most homogeneous length, fineness, maturity and strength characteristics possible. These characteristics were evaluated in 10 samples taken from each raw bale for analysis by HVI, FMT3, SCT Thermodetector and H2SD (Frydrych, 1998).

Table C-3: Stickiness data for the raw cottons.

	SCT	H2SD
Bale	Raw cotton	Raw cotton
AC1	0.4	0.5
AC2	0.3	0.8
AR02	14.1	9.3
AR05	30.5	17.8
AR07	14.3	15.4
AR08	19.7	23.9
AR14	34.1	37.7
AR16	30.5	41.1
AR17	52.5	42.3
AR18	39.3	38.0
ARNC1	12.8	24.0
ARNC2	12.0	21.7
AS01	13.0	20.8
AS02	55.7	43.6
AS04	13.3	18.5
AS05	62.8	61.2
AS06	39.1	49.0
AS08	43.3	42.4
AS09	12.3	23.3
AS10	30.3	29.6
AS13	17.1	21.3
AS14	20.5	36.6
AS15	32.8	57.8
AS16	9.4	17.3
AS19	7.3	13.1
AS20	8.9	15.5

Once each of the 26 bales had been characterized, the cotton was processed by industrial-scale carded spinning. The spinning facility was composed of two rooms with independent conditioning: a preparation room and a spinning room. The cotton fiber was processed successively by the following machines:

- Bale breaker (LAROCHE)
- Opener-cleaner (TRÜTZSCHLER RN)
- Opener-mixer (TRÜTZSCHLER RSK)
- Card (TRÜTZSCHLER DK 715)
- Drawing frame (RIETER D1/1)

- Roving frame (RIETER F1/1a)
- Ring spinning frame (SACM CF-6)
- Rotor spinning frame (SCHLAFHORST SE-9)
- Winder

C.1.2.3. Conditions and operating procedure

The order in which the bales were processed was randomized to avoid any bias in the interpretation of the results. Before actually starting the processing, the bale was homogenized by recycling between the RN opener and the LAROCHE breaker. This reduced the natural variability within each bale and thus improved the precision of the relationships between stickiness and spinning incidents. Once the homogenization was complete, the bale entered production at a temperature of $25 \pm 2^{\circ}\text{C}$ and a relative humidity of $47.5 \pm 2.5\%$. These hygrometric conditions correspond to those generally recommended for preparation. The card was set to a delivery speed of 120 m/min to produce a 5 ktex sliver. At the first drafting pass, the doubling was set at 6, sliver count at 4 ktex and delivery speed at 400 m/min. For the second drafting pass, only the doubling was modified, to 8. The 24 spindles on the roving frame were set at 900 rpm to produce a 0.5 ktex roving. The sliver and roving were then transferred to the spinning room where atmospheric conditions consisted of a temperature of $25 \pm 2^{\circ}\text{C}$ and a relative humidity of $57.5 \pm 2.5\%$. The ring spinning frame, with 100 spindles spinning at 8000 rpm, and the rotor spinning frame with 24 rotors spinning at 90000 rpm were set to produce 20 tex yarn with twist of 800 rpm.

During the spinning of each bale, the number of breaks, fiber wraps and stoppages for cleaning were recorded for each machine used. These incidents were then listed with respect to the part of the machine where they occurred and their cause. Thus, three principal types of incident were recorded for the card: breakage of the web, breakage of the sliver at the condenser and breakage of the sliver at the can coiler. Breakage were noted on the drawing frame at the feed creel, the roller drafting and the sliver condenser. Breakage on the roving frame were noted at the feed creel, the roller drafting and the flyer. Only two types of breakage could be monitored on the ring spinning frame: those concerning the roving and those the yarn. By contrast, several different incidents were possible on the rotor spinning frame. The number of yarn piecing and the efficiency at each step of the process could be determined thanks to the on-line management of the production. In addition to these automated recordings, the number of times the technician intervened in the process was also recorded for the four main structures in the process, i.e. the feed cylinder, the taker-in, the rotor and the yarn navel (Table C-4).

Table C-4: Frequency and list of machine check points.

Controls and samples per machine	Frequency
LAROCHE Bale breaker (figure C-1):	
- Point A	- end of test
- Point B	- end of test
- Point C	- end of test
- Point D	- end of test
- Point E	- end of test
- Point F	- end of test

Controls and samples per machine	Frequency
- Sample of 100 g of fibers at the outlet of the machine	- 10 times at regular intervals
Magnetic zigzag (figure C-2):	
- Point A	- end of test
Opener cleaner (TRÜTZSCHLER RN) (figure C-3):	
- Point A	- end of test
- Point B	- end of test
- Point C	- end of test
- Point D	- end of test
- Sampling of 100 g of fibers	- 10 times at regular intervals
Condenser (TRÜTZSCHLER LVS) (figure C-4):	
- Point A	- end of test
Opener – mixing machine (TRÜTZSCHLER RSK) (figure C-5):	
- Point A	- end of test
- Point B	- end of test
- Point C	- end of test
- Point D	- end of test
- Point E	- end of test
- Sampling of 100 g of fibers	- 10 times at regular intervals
Card (TRÜTZSCHLER DK 715) (figure C-6):	
- Point A	- end of test
- Point B	- end of test
- Point C	- end of test
- Point D	- end of test
- Point E	- end of test
- Point F	- end of test
- Point G	- end of test
- Point H	- end of test
- Sampling of 50 m of sliver	- each incident
- Sampling of 50 g of sliver	- each incident
- Sampling of flat wastes	- once at the beginning of the test
- Sampling of opener wastes	- 10 times at regular intervals
Drawing frame (RIETER D1/1) (figure C-7):	
- Point A	- end of test
- Point B	- end of test
- Sampling of 50 m of sliver during 1st and 2nd draft	- each incident
Flyer (RIETER F1/1a) (figures C-8 and C-9):	
- Point A	- once during the test
	- each incident

Controls and samples per machine	Frequency
<ul style="list-style-type: none"> - Point B - Sampling of 4 tubes: 1 position out of 6 	<ul style="list-style-type: none"> - each incident - one time per doffing
Ring spinning frame (SACM CF-6) (figure C-10 and C-11): <ul style="list-style-type: none"> - Point A - Point B - Point C - Sampling of 10 cops (sampling of 1 position out of 10) 	<ul style="list-style-type: none"> - each incident - each incident - each incident - 1 time per doffing
Winding machine: <ul style="list-style-type: none"> - Check of pieces in contact with yarn - Sampling of 4 non-cleared tubes - - Sampling of 4 cleared tubes 	<ul style="list-style-type: none"> - end of test - during the test - during the test
Open-end (SCHLAFHORST SE9) (figure C-12): <ul style="list-style-type: none"> - Point A - Point B - Point C - Point D - Point E - Sampling of 6 tubes (sampling of 1 position out of 4) 	<ul style="list-style-type: none"> - each incident - end of test - each incident - each incident - each incident - 1 time per shift (8 hours)

Observations were made to deduce the nature and the origin of the incidents to complete these checks and samples. Thus, the sliver or yarn breaks, rolling-up, etc ... were classified as to their origin. The time required for each step in the process was noted to deduce equipment productivity.

The processing equipment was cleaned thoroughly after each test to avoid contamination between consecutive tests. For the machines in the blowing room, around 10 kg of fibers were processed in sliver in order to remove all traces of stickiness. The efficiency of this method was tested in 2 independent studies while setting the equipment. The parts of the machines in contact with the cotton fibers were cleaned using soap and water, except the card where specific cleaning methods are used.

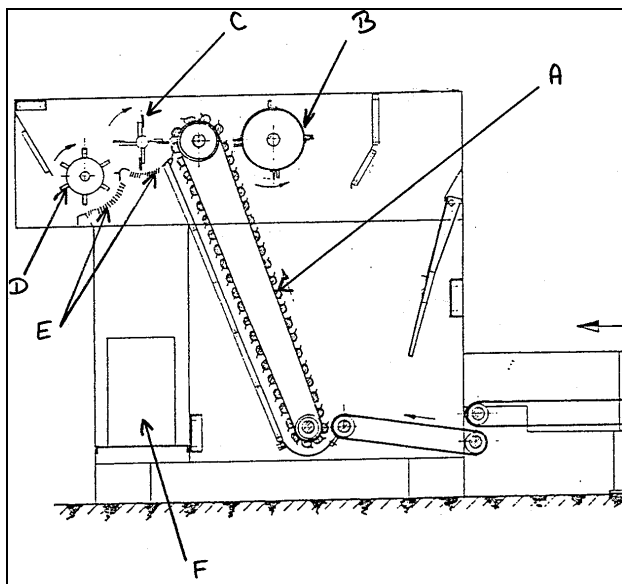


Figure C-1: Check of the bale breaker.

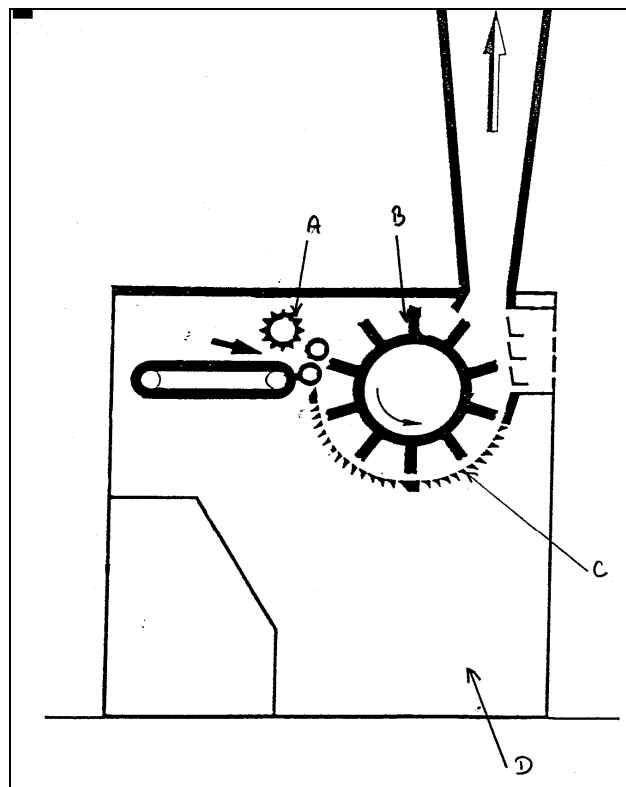


Figure C-3: Check of the RN opener cleaner.

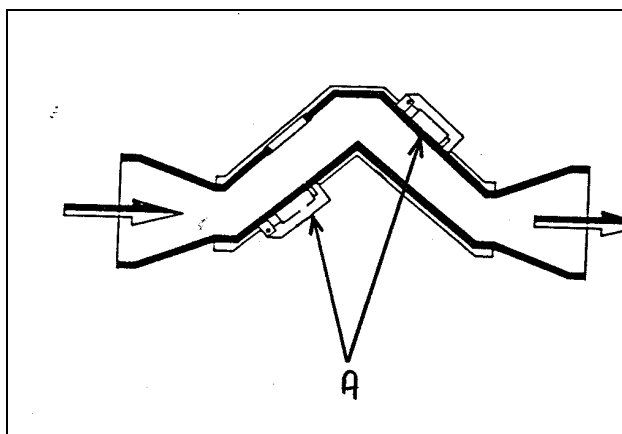


Figure C-2: Check of the magnetic zigzag.

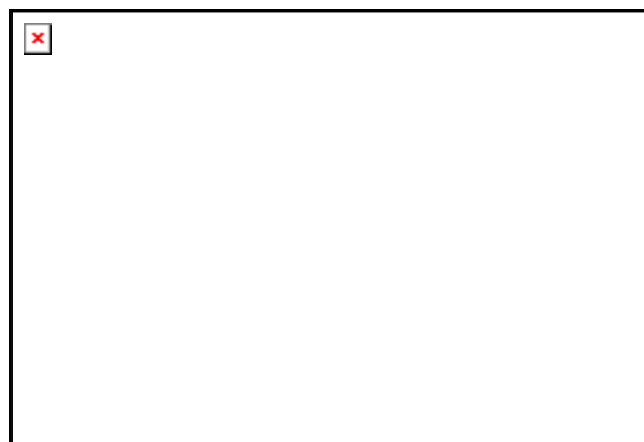


Figure C-4: Check of the LVS condenser.

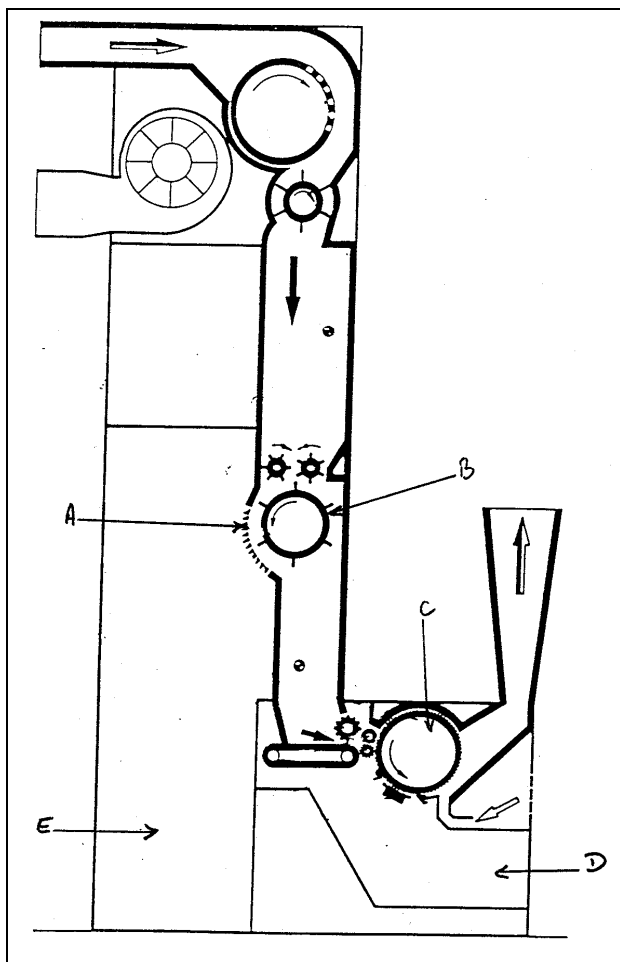


Figure C-5: Check of the RSK opener mixing machine.

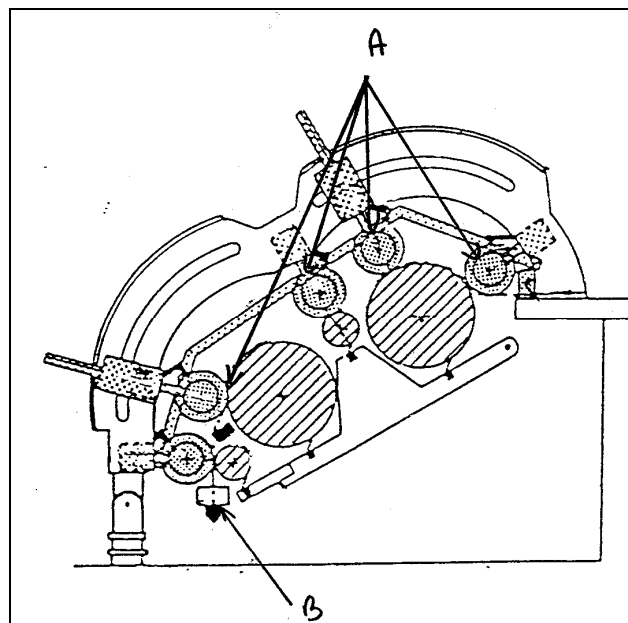


Figure C-7: Check of the drawing frame.

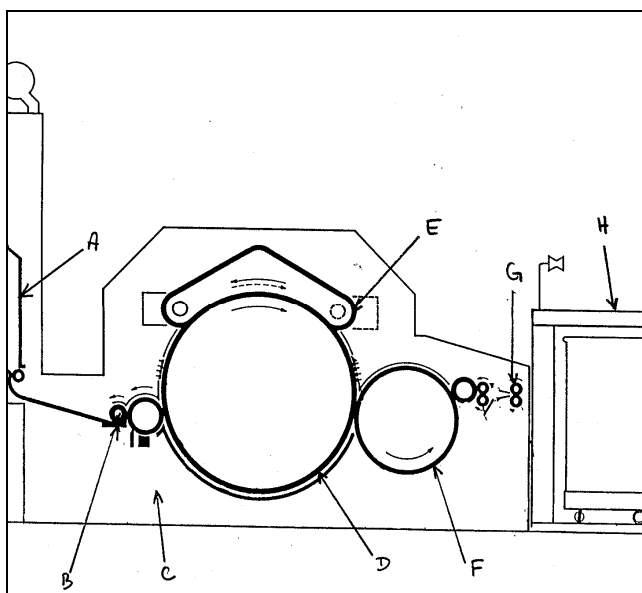


Figure C-6: Check of the card.

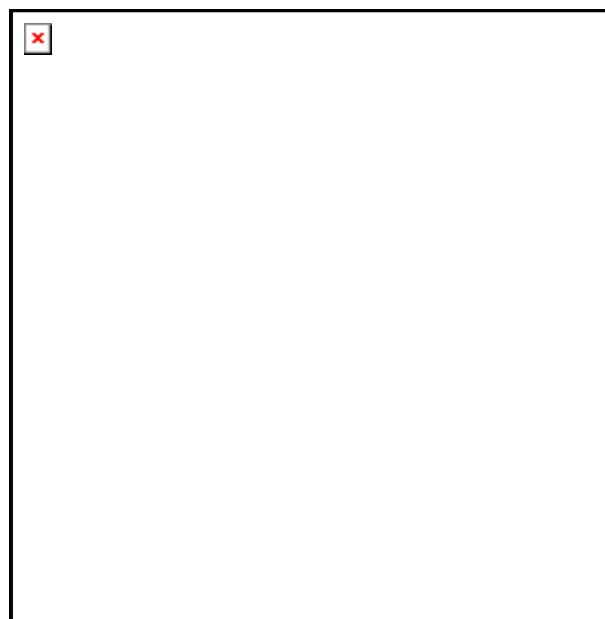


Figure C-8: Check of the flyer.

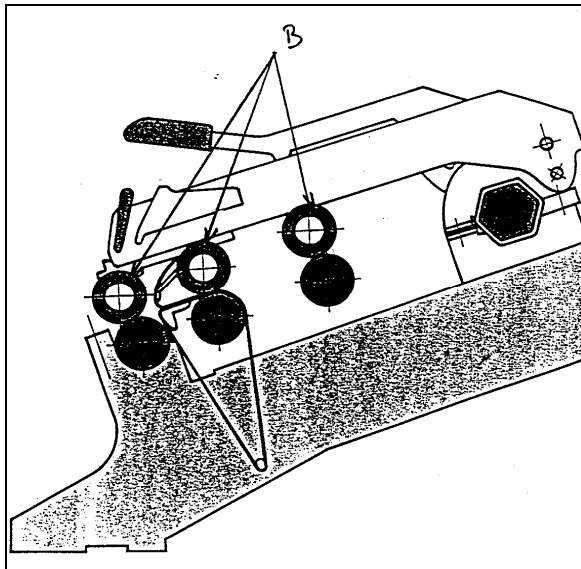


Figure C-9: Check of the drafting zone on the flyer.

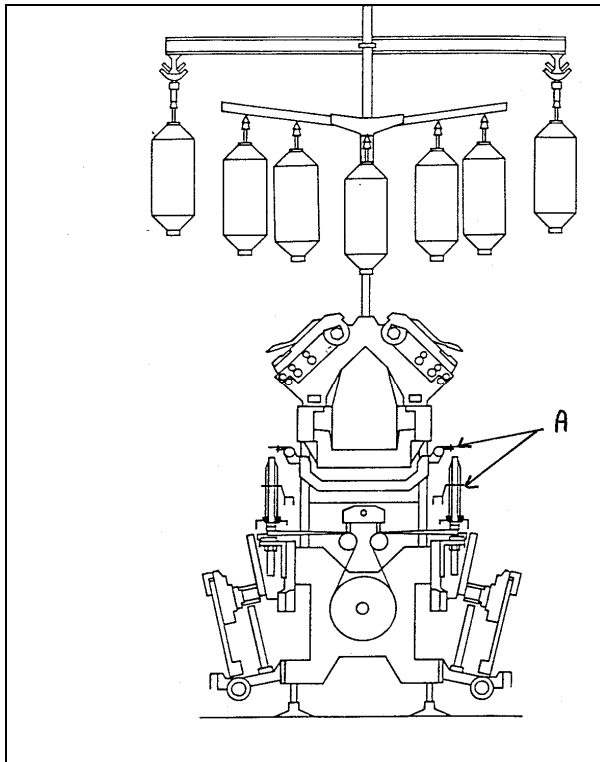


Figure C-10: Check of the ring spinning frame.

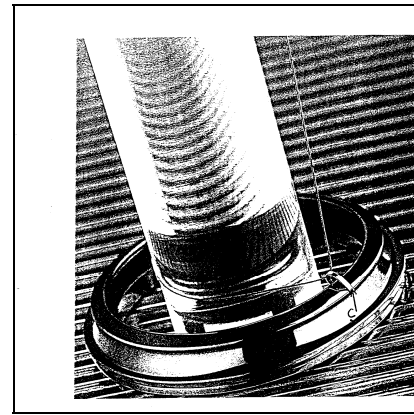


Figure C-11: Check of the ring spinning position.

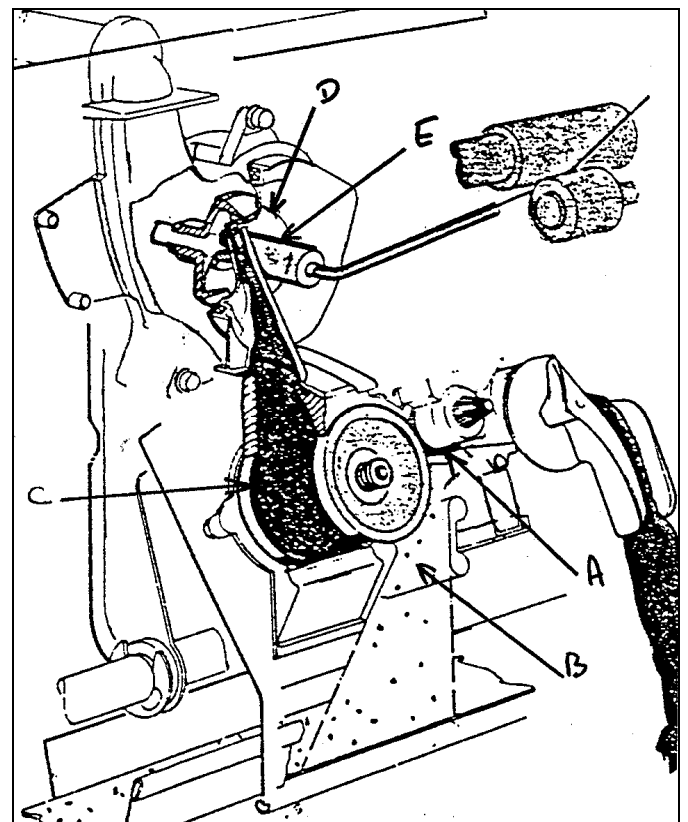


Figure C-12: Check of the open-end spinning position.

The results were used to calculate the breakage incidence and the efficiency of the different machines. Breakage incidence was expressed by unit length of the roving, sliver or yarn to avoid any effects caused by machine stoppages. Thus, when considering the card, total breakage corresponded to the number of breaks per 100 km of sliver. This number is therefore equivalent to the hourly breakage rate in a card room containing fourteen machines. The breaks on the drawing frame were also expressed for 100 km of sliver, i.e. equivalent to the hourly breakage rate of two machines working at 800 m/min. The breakage rate of the roving frame was calculated for 100 km of roving, equivalent to the hourly breakage rate for 100 spindles (i.e. approximately two roving frames with 48 spindles each). Breaks were expressed per 1000 spindles hour for the ring spinning frame and per 240 rotors hour for the rotor spinning frame.

These productivity parameters were then compared with stickiness results determined using three different methods:

- SCT thermodetector measuring the number of sticky points (*SCT*),
- H2SD measuring the number of sticky points (*H2SD*), their total size (*Size-H2SD*) and their size category (*Small*, *Medium* and *Large*),
- HPLC measuring the content of the different sugars: Inositol (*I*), Trehalose (*T*), Glucose (*G*), Fructose (*F*), Trehalulose (*W*), Melezitose (*M*) and Sucrose (*S*).

Table C-5: Main sampling and quality evaluations.

Machine	Sample	Test	Number of measures
LAROCHE Bale breaker	10 fiber samples (100 g)	Stickiness SCT	1 mes./sample
		Stickiness H2SD	1 mes./sample
	1 waste sample	Stickiness SCT	3 mes./sample
RN Opener cleaner	10 fiber samples (100 g)	Stickiness SCT	1 mes./sample
		Stickiness H2SD	1 mes./sample
	1 waste sample	Stickiness SCT	3 mes./sample
RSK Opener mixer	10 finer samples (100 g)	Stickiness SCT	1 mes./sample
		Stickiness H2SD	1 mes./sample
		Sugars HPLC	3 mes./test
	2 waste samples	Stickiness SCT	3 mes./sample
DK 715 Card	10 fiber samples (100 g)	Stickiness SCT	1 mes./sample
		Stickiness H2SD	1 mes./sample
	2 sliver samples (50 m)	CV% UT3	1 mes./sample
	2 waste samples	Stickiness SCT	3 mes./sample
Drawing frame	2 sliver samples (50 m)	CV% UT3	1 mes./sample
Flyer	4 bobbins per doffing	CV% UT3	1 mes/bobbin/doffing

Machine	Sample	Test	Number of measures
Ring spinning frame	10 cops per doffing	CV% UT3 Thin –50% Thick +50% Neps +200% Yarn count Hairiness	1 mes. UT3 on 1000 m per cop and per doffing
		Strength g/tex Elongation% Work to break	10 breaks Tensorapid 3 per cop and per doffing
Open-end	6 bobbins per day	CV% UT3 Thin –50% Thick +50% Neps +280% Yarn count Hairiness	1 mes. UT3 on 1000 m per bobbin and per day
		Strength g/tex Elongation% Work to break	10 breaks Tensorapid 3 per cop and per doffing
	1 bobbin per day	Defaults CLASSIMAT	1 mes. Per test
		Detailed analysis	1 mes. on 2000 m per bobbin and per day
Winder	4 cleared bobbins	CV% UT3 Thin –50% Thick +50% Neps +200% Yarn count Hairiness	1 mes. UT3 on 1000 m per bobbin
		Strength g/tex Elongation% Work to break	10 breaks Tensorapid3 per cop and per doffing
	4 non-cleared bobbins	CV% UT3 Thin –50% Thick +50% Neps +200% Yarn count Hairiness	1 mes. UT3 on 1000 m per bobbin

Machine	Sample	Test	Number of measures
		Strength g/tex	1 mes. Tensorapid3 on 1000 m per bobbin
		Elongation%	
		Work to break	
		Detailed analysis UT3	1 mes. per bobbin
		Defects CLASSIMAT	1 mes. per test

Samples of cotton-fiber, sliver, roving, yarn and waste were taken to evaluate the effects of the stickiness of the quality of these products (Table C-5). Thus, ten fiber samples were taken at regular intervals from the breaker, RN opener, RSK opener and the card. These samples were analyzed on the SCT and H2SD thermodetector to evaluate stickiness at the different steps of the process. In addition, RSK samples were analyzed by HPLC. Samples of sliver and roving were used to evaluate regularity at the card, drawing frame and roving frame. Yarn quality was evaluated in samples taken from the yarn bobbins and packages.

C.1.3. Results and Discussion: effect on productivity

It should be noted that 2 bales (AS15 and AR17) could not be processed under these normal conditions. The results were therefore based on 24 bales. A specific study was conducted on 2 bales in very low relative humidity. The results of this experiment are described in paragraph C.2.

C.1.3.1. Choice of the best predictor of stickiness problem during spinning

Since stickiness appears to be worsening, detection methods appear with a strong effort to decrease the time consumption of the test.

Recently-acquired knowledge has improved our understanding of the role played by different sugars in the stickiness effect during spinning. It is now recognized that simple chemical tests are not predictive of the problems encountered during spinning.

Since 1994, the ITMF (*International Textiles Manufacturers Federation*) committee has been recommending the SCT test for the stickiness evaluation on fiber samples (Reference ITMF: 420/94).

When research described here was conducted, no reliable relations between stickiness measurements and disruptions during spinning had been published. Indeed, cottons were classified as ‘non-sticky’, ‘lightly sticky’, .. to ‘heavily sticky’. These classes were obtained by linking SCT results to mini-card grading systems (Frydrych, 1996), and did not predict the extent of the disruptions encountered during industrial spinning.

We therefore attempted to define a stickiness indicator based on quantitative determinations. We then compared the three main methods of measuring stickiness (SCT, H2SD, sugars by HPLC) and matched these to productivity and quality criteria. First, the data from these three techniques was analyzed and compared.

C.1.3.2. Relations between SCT, H2SD and HPLC results

If relations between SCT and H2SD data are well-known, it is interesting to compare these results to sugar content as measured by HPLC. This may help get a better prediction of the problems during spinning

Table C-6 and Table C-7 give the results and the correlation coefficients observed between

stickiness and sugar measurements on samples taken at the RSK opener:

- *H2SD*: number of sticky points measured by H2SD (*H2SD* counting);
- *Small*: number of sticky points whose size, measured by H2SD, is in the range [1,7; 9] mm²;
- *Medium*: number of sticky points whose size, measured by H2SD, is in the range [9; 18] mm²;
- *Large*: number of sticky points whose size, measured by H2SD, is larger than > 18 mm²;
- *TMH2SD* : mean size of the sticky points as measured by H2SD;
- *TTH2SD* : total size (sum of the sizes measured by H2SD);
- *SCT* : number of sticky points as measured by SCT (*SCT* counting);
- *I* : percentage of inositol (% of the fiber mass) measured by HPLC;
- *T* : percentage of trehalose (% of the fiber mass) measured by HPLC;
- *G* : percentage of glucose (% of the fiber mass) measured by HPLC;
- *F* : percentage of fructose (% of the fiber mass) measured by HPLC;
- *W* : percentage of trehalulose (% of the fiber mass) measured by HPLC;
- *S* : percentage of saccharose (% of the fiber mass) measured by HPLC;
- *M* : percentage of melezitose (% of the fiber mass) measured by HPLC;
- *Stotal* : total percentage of sugars *I*, *T*, *G*, *F*, *W*, *S* and *M* (% of the fiber mass) .

Table C-6: HPLC results.

Bale	Ginning	Sample	H2SD	I	T	G	F	W	S	M	Stotal
AC1	S	RSK	3.1	0.0302	0.0539	0.1061	0.0988	0.0087	0.0064	0.0393	0.3435
AC2	S	RSK	1.4	0.0269	0.0335	0.0797	0.0836	0.0032	0.0129	0.0295	0.2693
AR02	R	RSK	8.6	0.0643	0.0039	0.1527	0.2366	0.0194	0.0541	0.0442	0.5753
AR05	R	RSK	24.3	0.0639	0.0109	0.1567	0.2735	0.0324	0.1025	0.0557	0.6955
AR07	R	RSK	16.2	0.0469	0.0058	0.0836	0.0984	0.0277	0.0426	0.0267	0.3317
AR08	R	RSK	24.4	0.0523	0.0062	0.127	0.1863	0.0424	0.0741	0.0425	0.5308
AR14	R	RSK	22.3	0.0575	0.0091	0.1637	0.235	0.0462	0.1108	0.0532	0.6755
AR16	R	RSK	28.8	0.0517	0.0114	0.1127	0.1643	0.0271	0.0636	0.0422	0.473
AR18	R	RSK	34.5	0.0542	0.0073	0.1025	0.1574	0.0104	0.0601	0.0321	0.424
ARNC1	R	RSK	8	0.0631	0.0074	0.2434	0.1921	0.0196	0.0303	0.0413	0.5971
ARNC2	R	RSK	11	0.0604	0.0073	0.225	0.1763	0.0128	0.0229	0.0362	0.541
AS01	S	RSK	16.4	0.0584	0.0147	0.1286	0.1475	0.0032	0.0308	0.0309	0.4141
AS02	S	RSK	37.3	0.0647	0.0179	0.1659	0.2858	0.0467	0.1482	0.0641	0.7934
AS04	S	RSK	14.6	0.065	0.0174	0.135	0.212	0.0099	0.0558	0.0373	0.5325
AS05	S	RSK	49.5	0.0593	0.0117	0.2159	0.3466	0.094	0.1836	0.0635	0.9745
AS06	S	RSK	31.9	0.0631	0.0091	0.1577	0.2545	0.0767	0.1082	0.0576	0.7269
AS08	S	RSK	29.2	0.0608	0.0172	0.1105	0.1757	0.0297	0.117	0.0448	0.5557
AS09	S	RSK	12.9	0.063	0.0223	0.1246	0.163	0.0144	0.0422	0.0405	0.4701

Bale	Ginning	Sample	H2SD	I	T	G	F	W	S	M	Stotal
AS10	S	RSK	28.5	0.0606	0.0219	0.1666	0.2404	0.0262	0.1117	0.0481	0.6755
AS13	S	RSK	13	0.0578	0.0065	0.1536	0.1999	0.012	0.0452	0.0337	0.5087
AS14	S	RSK	22	0.0674	0.0102	0.1714	0.2999	0.0217	0.1422	0.0529	0.7658
AS16	S	RSK	11.1	0.0563	0.0069	0.1717	0.2776	0.017	0.0297	0.0349	0.5941
AS19	S	RSK	9.6	0.0605	0.005	0.2773	0.2077	0.0165	0.0271	0.0368	0.6309
AS20	S	RSK	9.4	0.0682	0.0054	0.2807	0.2366	0.0202	0.0303	0.0433	0.6847

Table C-7: Correlation coefficients between H2SD (RSK samples), SCT et HPLC results.

Variables	H2SD	Small	Medium	Large	TMH2SD	TTH2SD	SCT
H2SD	1						
Small	0.991	1					
Medium	0.974	0.961	1				
Large	0.949	0.904	0.910	1			
TMH2SD	0.577	0.503	0.573	0.728	1		
TTH2SD	0.940	0.897	0.910	0.982	0.705	1	
SCT	0.891	0.873	0.836	0.887	0.521	0.892	1
I	NS	NS	NS	NS	0.629	NS	NS
T	NS	NS	NS	NS	NS	NS	NS
G	NS	NS	NS	NS	NS	NS	NS
F	0.533	0.534	0.519	0.487	0.420	0.517	0.589
W	0.754	0.772	0.721	0.672	NS	0.703	0.818
S	0.862	0.872	0.847	0.768	0.429	0.786	0.835
M	0.659	0.677	0.664	0.564	NS	0.590	0.721
Stotal	0.600	0.597	0.608	0.548	0.445	0.584	0.687

Critical R at the 5% level = 0.4044

NS: non significant

We chose the RSK samples because the samples here are more homogeneous and give more precise HPLC measurements.

The results confirmed the significant relationship between H2SD and SCT measurements. These relationship also are significant on raw cotton samples as illustrated by Figure C-13 and the following equation where the offset is not different from 0 and the slope is almost not different from 1.

$$SCT_{Raw} = 0.99 \times H2SD_{Raw} - 3.16$$

Concerning sugar contents, inositol, trehalose and glucose contents did not correlate with SCT and H2SD results. Fructose was lightly correlated with the number of sticky points. On the other hand, melezitose, trehalulose and mainly saccharose were well correlated with SCT and H2SD measurements. These relations are given in Figure C-14, Figure C-15 and Figure C-16. The total percentage of sugars showed a low, but significant, correlation with SCT and H2SD results. Figure C-17 shows the dispersion of the *Stotal* data compared to SCT and H2SD total number of sticky points.

The correlation coefficients showed comparable trends for the different methods used to measure stickiness. However, the inter-connection between the different variables limited the

complementarity of these measurements. Thus, we will probably have to choose only one criterion to measure stickiness and predict its effect during spinning.

C.1.3.3. What is the best indicator ?

By best indicator, we mean the measurement that gives the best correlation coefficient with the disruptions observed during spinning, for both productivity and quality parameters.

Efficiencies and breakages were calculated for all the machines. Breakages were expressed per unit length of produce (sliver, ..., yarn) to be independent of time and operator know-how. Thus, breakages provide information about productivity that is completed by machine efficiency, the latter being dependent on operator work-load.

Different breakage rates were calculated depending on machine type, the nature of the breaks and on their causes. However, to simplify the presentation of the results, only efficiencies and breakages are presented here

Quality-wise, the characterization of the samples collected in the course of the process provides information about yarn evenness, imperfections, and resistance parameters from the sliver to the yarn in most of the cases.

These results were matched to the stickiness determination performed on RSK samples. The fibers are well mixed at this point and these samples are therefore representative of the raw material with low variability of the stickiness within the fibers. This can be observed in Table C-8 where the dispersion indexes (ratio of the variance to the mean) are reported for each step in the process where samples can be taken for stickiness measurements. The best place to get samples for both measuring devices is the RSK opener-mixer.

Table C-8: Over-dispersion index of the SCT and H2SD number of sticky points at different operating levels.

	SCT	H2SD
Raw cotton	3.01	4.40
Laroche Opener	2.11	2.71
RN Opener Cleaner	2.27	2.13
RSK Opener mixer	1.75	1.93
Card sliver	2.44	1.20

In parallel to the comparison between the SCT and H2SD number of sticky points, we also compared the quality and productivity parameters with the parameters described in Table C-7

Correlation coefficients between stickiness measurements and productivity parameters are given in Table C-9

Correlation coefficients between stickiness measurement and quality parameters are given in Table C-10

Table C-9: Correlation coefficients r between stickiness measurements and productivity criteria.

Variable	H2SD	Small	Medium	Large	TMH2SD	TTH2SD	SCT	I	T	G	F	W	S	M	Stotal
C-CT100km	0.591	0.578	0.580	0.555	NS	0.532	NS	NS	NS	NS	NS	NS	NS	NS	NS
C-Efficiency	-0.726	-0.735	-0.705	-0.634	NS	-0.677	-0.657	NS	NS	NS	-0.528	-0.738	-0.721	-0.572	-0.603
E1-CT100km	0.786	0.755	0.789	0.774	0.443	0.835	0.812	NS	NS	NS	0.560	0.662	0.764	0.644	0.643
E1-Efficiency	-0.603	-0.585	-0.631	-0.557	NS	-0.578	-0.608	NS	NS	NS	NS	-0.498	-0.580	-0.464	-0.461
E2-CT100km	0.719	0.703	0.680	0.704	NS	0.771	0.851	NS	NS	NS	0.642	0.774	0.750	0.680	0.735
E2-Efficiency	-0.535	-0.519	-0.497	-0.531	-0.442	-0.567	-0.645	NS	NS	NS	-0.508	-0.394	-0.615	-0.452	-0.564
B-CT100km	0.746	0.771	0.659	0.675	NS	0.712	0.757	NS	NS	NS	0.588	0.782	0.754	0.707	0.652
B-Efficiency	-0.763	-0.791	-0.744	-0.638	-0.475	-0.628	-0.638	NS	NS	NS	-0.556	-0.626	-0.768	-0.627	-0.613
CAF-TC1000BH	0.816	0.832	0.749	0.763	NS	0.728	0.755	NS	NS	NS	0.440	0.697	0.746	0.691	0.505
OE- Efficiency	-0.659	-0.671	-0.660	-0.565	NS	-0.529	-0.674	NS	NS	NS	NS	-0.645	-0.585	-0.512	-0.420
OE-Y-P240BH	0.654	0.678	0.689	0.532	NS	0.487	0.476	NS	NS	NS	NS	0.572	0.526	0.463	NS
OE-LR240BH	0.737	0.760	0.711	0.638	NS	0.564	0.710	NS	NS	NS	NS	0.607	0.615	0.612	NS

Risk α r critical

0.1% 0.6402

1% 0.5256

5% 0.4132

SCT: number of SCT sticky points

H2SD: number of H2SD sticky points

Small: number of sticky points whose size is included between 1.7 and 9 mm²

Medium: number of sticky points whose size is included between 9 and 18 mm²

Large: number of sticky points whose size is larger than 18 mm²

TMH2SD: average size of the H2SD sticky points

TTH2SD: total size of the H2SD sticky points

I: inositol

T: trehalose

G: glucose

F: fructose

W: trehalulose

S: saccharose or sucrose

M: melezitose

Stotal: percentage of total sugars

C-CT100km: total nb. of breaks per 100 km of card sliver

C- Efficiency: card efficiency (efficiency = rendement)

E1-CT100km: total nb. of breaks per 100 km of drawing frame sliver (1° draft)

E1- Efficiency: drawing frame efficiency (1° draft)

E2-CT100km: total nb. of breaks per 100 km of drawing frame sliver (2°draft)

E2- Efficiency: efficiency of the drawing frame (2°draft)

B-CT100km: total nb. of breaks per 100 km on the flyer

B- Efficiency: efficiency of the flyer

CAF-TC1000BH: breakage per 1000 spindles/hour on the ring spinning frame

OE- Efficiency: efficiency of the Open-end machine

OE-Y-P240BH: number of piecings per hour for 240 pen end positions

OE-LR240BH: number of interventions per hour for 240 open end positions.

Table C-10: Correlation coefficients r between stickiness determinations and quality criteria.

Variable	H2SD	Small	Medium	Large	TMH2SD	TTH2SD	SCT	I	T	G	F	W	S	M	Stotal
C-CV%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
E1-CV%	NS	0.420	0.389	0.316	NS	NS	NS	NS	NS	-0.522	NS	NS	NS	NS	NS
E2-CV%	NS	0.144	0.037	0.113	NS	NS	NS	NS	NS	-0.481	NS	NS	NS	NS	NS
B-CV%	0.466	0.469	0.410	0.444	NS	NS	NS	NS	NS	NS	NS	NS	0.506	NS	NS
CAF-UT3-CV%	0.801	0.797	0.776	0.763	0.586	0.748	0.757	NS	NS	NS	NS	0.542	0.779	0.508	NS
CAF-UT3-50%	0.628	0.615	0.625	0.621	0.607	0.597	0.536	NS	NS	NS	NS	NS	0.535	NS	NS
CAF-UT3+50%	0.819	0.815	0.791	0.776	0.523	0.776	0.831	NS	NS	NS	0.504	0.615	0.875	0.680	0.561
CAF-UT3-Neps	0.843	0.861	0.826	0.755	NS	0.757	0.841	NS	NS	NS	0.422	0.730	0.874	0.752	0.512
CAF-Hairiness	0.520	0.537	0.487	0.487	0.515	NS	NS	NS	-0.457	NS	NS	NS	NS	NS	NS
CAF-Elongation	NS	-0.326	-0.260	-0.313	NS	NS	NS	NS	NS	0.413	NS	NS	NS	NS	NS
CAF-Strength	-0.570	-0.560	-0.540	-0.594	-0.619	-0.566	-0.486	NS	NS	NS	NS	NS	NS	NS	NS
CAF-work	-0.462	-0.464	-0.409	-0.469	-0.510	-0.444	NS	NS	NS	NS	NS	NS	NS	NS	NS
OE-UT3-CV%	-0.725	-0.733	-0.728	-0.649	-0.547	-0.623	-0.528	-0.522	0.513	NS	-0.502	-0.592	-0.717	-0.474	-0.534
OE-UT3-50%	-0.794	-0.815	-0.738	-0.706	-0.454	-0.652	-0.623	-0.420	NS	NS	-0.460	-0.595	-0.769	-0.502	-0.462
OE-UT3+50%	-0.710	-0.719	-0.706	-0.633	-0.645	-0.577	-0.542	-0.740	0.651	NS	-0.589	-0.524	-0.660	-0.484	-0.611
OE-UT3-Neps	-0.612	-0.609	-0.601	-0.568	-0.654	-0.518	-0.488	-0.778	0.583	NS	-0.641	-0.423	-0.576	-0.444	-0.630
OE-Hairiness	0.477	0.493	0.467	0.432	0.590	0.425	NS	0.554	-0.563	NS	0.439	NS	0.469	NS	0.415
OE-Elongation	NS	-0.185	-0.189	-0.172	NS	NS	NS	NS	NS	0.428	NS	NS	NS	NS	NS
OE-Strength	-0.549	-0.541	-0.603	-0.514	-0.548	-0.522	-0.443	NS	NS	NS	NS	NS	-0.483	NS	NS
OE-Work	-0.472	-0.464	-0.495	-0.455	-0.478	-0.465	NS	NS	NS	NS	NS	NS	-0.474	NS	NS

C-CV%: CV% mass variation on card sliver

E1-CV%: CV% mass variation on 1st draft drawing frame

E2-CV%: CV% mass variation on 2nd draft drawing frame

B-CV%: CV% mass variation on flyer yarn

CAF-UT3-CV%: CV% mass variation on ring spun yarn

CAF-UT3-50%: Nb of thin places per km of ring spun yarn

CAF-UT3+50%: Nb of thick places per km of ring spun yarn

CAF-UT3-Neps: Nb of neps on km of ring spun yarn

CAF-Hairiness: Hairiness of the ring spun yarn

CAF-Elongation: Elongation (%) of the ring spun yarn

CAF-Strength: Strength (cN/tex) of the ring spun yarn

CAF-Work: Work to break (N.cm) of RS yarn

OE-UT3-CV%: CV% mass variation of the OE yarn

OE-UT3-50%: Nb of thin places per km of OE yarn

OE-UT3+50%: Nb of thick places per km of OE yarn

OE-UT3-Neps: Nb of neps per km of OE yarn

OE-Hairiness: Hairiness of OE yarn

OE-Elongation: Elongation (%) of OE yarn

OE-Strength: Strength (cN/tex) of OE yarn

OE-Work: Work to break (N.cm) of OE yarn

The correlation coefficients show that the number of sticky points measured by SCT, the number measured by H2SD and the percentage of melezitose, trehalulose and saccharose are correlated with most of the productivity parameters in the spinning mill. Concerning the sticky point sizes, the 3 classes (small, medium and large) and the total size of the sticky points (*TTH2SD*) show a comparable to the number of sticky points measured by *H2SD*. On the other hand, the average *TMH2SD* size was rarely significantly linked to spinning parameters.

The different types of sugars included on the cotton fibers were characterized by HPLC. The total amount of sugar (Stotal, expressed in percent of the fiber sample) was distributed for the cottons used in this experiment as illustrated by Figure C-18. The darker bars corresponds to the cotton considered as non sticky from Central Asia.

HPLC assayed the individual sugars given here in percent of the sample mass (Figure C-19, includes Central Asia cottons). When the different sugar types were compared without Central Asia (Figure C-20) or with these cottons (Figure C-21), significant differences appeared. From the bibliography, we know that some sugars are constituent of both entomological and physiological sugars. It is also known that insect honeydew from Aphids or White flies are different in terms of sugars types. However, from these characterization results, it is not possible to deduce the true origin of the honeydew. It may be from Aphids, white flies and/or physiological sugars.

For the last type of sugars, we know that they may degrade over a short period of time (Hequet, 1999). The spinning experiments were done on a period of time that could have been longer than the degradation period of these physiological sugars, inducing a possible bias in some recorded conclusions.

Melezitose and trehalulose are important to analyse since there are considered as main sugars involved in entomological sugars. On the other hand, saccharose could not explain alone the stickiness during spinning because it is linked to physiological sugars (Hequet & Wyatt 1999).

Hendrix et al (1992) analyzed *A. gossypii* and *B. tabacci* honeydew using HPLC methodology (Table C-11).

Table C-11: Sugar content (%) of insect honeydew by HPLC (Hendrix et al, 1992).

Insect	Monosaccharides	Sucrose	Turanose	Trehalulose	Melezitose
<i>A. gossypii</i> on <i>G. hirsutum</i>	24.6	11.6	0.0	1.1	38.3
<i>B. tabaci</i> on <i>G. hirsutum</i>	18.9	16.0	1.0	43.8	16.8

From this table, and if only Melezitose and Trehalulose are considered, it can be seen that *A. gossypii* mostly contains Melezitose (97%) and some Trehalulose (3%) whereas *B. tabaci*, honeydew contains more Trehalulose (72%) than Melezitose (38%). All honeydew deposits contain relative high levels of monosaccharides (glucose and fructose) and bisaccharides (sucrose).

All cottons in this project contained Melezitose and Trehalulose (Table C-6). This indicates that these cottons were contaminated by whiteflies at least, and maybe by *Aphids* + whiteflies. Only one bale was possibly contaminated by *Aphids* alone. Thus, conclusion can be drawn about the type of infestation solely from the sugar contents, without any information available from the field.

The bales from Central Asia (AC1 and AC2) contained less physiological sugars (glucose and fructose) than Sudanese bales. In this experiment, we were not able to obtain non-sticky bales from Sudan. Thus, we cannot deduce any effect of physiological sugars compared to entomological sugar to the stickiness potential manifestation. However, it was noted that stickiness increased with the sucrose content.

It should be noted that physiological sugars may disappear over time (Hequet, 1999).

A comparison of the number of H2SD sticky points with the melezitose and trehalulose contents underlined the advantages of the H2SD readings. Indeed, the best correlation coefficients to productivity and quality parameters were obtained with H2SD. Correlation coefficients with melezitose and trehalulose contents were rarely higher than with the H2SD count, and these sugars did not correlate to all the parameters that correlated with H2SD

As far as disruptions during spinning are concerned, the HPLC results did not provide any supplementary information beyond that furnished by the H2SD and SCT counts. In view of the time and cost of the HPLC analysis, the choice of predictive method is therefore between H2SD and SCT. Because of its cost and the operator effect, SCT is not entirely suitable for precise and reproducible measurements. Thus, H2SD seems to be the most appropriate method for measuring stickiness in our research. However, in some cases in the below text, some relations will be given with other stickiness estimators.

C.1.3.4. Contribution of sticky point sizes in the expression of stickiness during spinning

Based on the assumption that a large sticky point will not induce the same disruption as a small point, the sticky point were divided into 3 categories (small, medium and large). We have already observed that this classification of the sticky points according to size does not provide any helpful information in explaining the problems encountered during the spinning operations.

To improve the quality of the predictive models, we tried to use the individual sizes of sticky points to explain the problems encountered during the spinning operations. The collection of such information was rendered possible by the use of specific software developed by Cirad to achieve this objective. For any sticky point detected by the image analysis software on each single image, the following information was recorded in text files:

- coordinates of the sticky point in the image, x and y in pixels
- width and length of the sticky point, dx and dy in pixels
- surface area of the sticky point, S in pixels

This information was then used to calculate other parameters such as proportionality ratio (dx/dy) and surface ratio (S/(dx.dy)).

Some of this information was used to define a new variable that places more weight on the size of sticky points: if X is the variable « size of each sticky point », the number of points is a transformation of X where all sticky points have the same weight. In other words, the counting is a transformation of the size without weighting compared to this one. This means that the total size TTH2SD is a transformation of X with a weighting equal to X for every sticky point.

Thus, we look for a transformation $Y = f(X)$ which would improve the correlation coefficients with the troubles during the spinning operations. Some transformations were tested, in particular Cox-box ($Y = X^a$ with $y = \log x$ for $a=0$) and a threshold function ($Y = \text{number of sticky points whose size is larger than a given threshold } X$). None of these functions bring

improvement in the observed correlation coefficients with the productivity and quality criteria.

Results from HPLC and H2SD demonstrate that the stickiness phenomenon is complex, and that further research is required to evaluate the effects of the different constitutive sugars in the honeydew. In this way, bales could be selected from fields only infested by white flies, others by Aphids, and others by a mix of these insects. These bales could then go through the same process as that described here.

To conclude, the fact that we did not succeed in using the sticky point size in the definition of the best stickiness predictor does not mean that this variable has no effect on the spinning process. In fact, if the H2SD image analysis principle is considered carefully, the measured size does not always correspond to the real size on the aluminum foil. Indeed, the measurement is an apparent size estimation due to scattered illumination of the fibers and the sugars that stay on the aluminum foil. This induces an over-estimation of the size of the sticky points. Thus, the evaluation of the smallest sticky points is biased. Some research is currently ongoing outside this project so that future measurements are more accurate and this could modify all the conclusions drawn here. In fact, it is very likely that the sticky points size distribution will be modified and this could well alter the conclusions drawn as regards the impact of sticky points on the spinning process. Thus, the different size categories could explain specific productivity of quality problems encountered in the spinning mill.

C.1.3.5. Results and discussion

Of the 26 bales selected for this spinning study, only 24 could be spun, and only 23 bales were considered for data analysis (due to problems in the conditioning rooms, bale AS06 was removed). The processing of the other two was impossible because of card clogging. Both of these bales were very sticky. One had been roller ginned and showed 42 sticky points (H2SD measurement). The other had been saw ginned and showed 58 sticky points. We were nevertheless able to spin another bale of similar stickiness, but with great difficulty and extremely low efficiency. Fifty H2SD sticky points would appear to be the threshold above which the stickiness immediately blocks the process when the opening operation is conducted at a relative humidity of 45 to 50%.

No particular stickiness effects occurred during the opening of the other 24 bales, i.e. no problems were encountered from the bale breaker to the card feeder. An inspection of the magnetic baffles, condenser and most parts of the machines in contact with the fiber did not reveal any fouling that required machine stoppage. Traces of stickiness were nevertheless noted regularly on the breaker needles and in the waste produced by all the machines. It is therefore very likely that certain very sticky cottons would have clogged this section of the line if production had continued for several days. Detecting clogging of the piping, condensers and magnetic baffles would therefore require a specific study with larger quantities of starting materials.

The machines further downstream in the spinning process were all adversely affected by cotton stickiness. From the card to the spinning frames, the entire production line reacted to stickiness, suffering decreased efficiency and increased breakage. Some examples of the problems that occurred during the spinning process are shown in Slide C-6 to Slide B-34 along with cleaning operations on the production machines up to the spinning machines.

C.1.3.6. Card

Card performance was closely related to cotton stickiness. The stickiness measurements showed a negative correlation with card efficiency and all the correlation coefficients were of

approximately the same order of magnitude. The closest correlation coefficients were obtained with the number of H2SD sticky points - physical measurement - and with the trehalulose levels (W) - chemical measurement. Figure C-22 shows the fitting of a regression line where efficiency is plotted against the number of H2SD sticky points. The 94% efficiency in the absence of any stickiness decreases in a linear manner by 6.5% for 10 H2SD sticky points (Equation C-1).

$$\text{Card-EFF.\%} = 93.7 - 0.653 \text{ H2SD}$$

(Equation C-1)

As far as breakages are concerned, no correlation could be detected between the total number per 100 km of sliver and the sugar levels determined by HPLC. Therefore, only the H2SD results could be used for this parameter (Figure C-23). The number of breaks increased in a linear manner with stickiness ((Equation C-2) but, as already seen for efficiency, the results obtained showed considerable dispersion around the regression line.

$$\text{Card-breakages} = 6.94 + 0.602 \text{ H2SD}$$

(Equation C-2)

C.1.3.7. Drawing frame

The performance of the drawing frame in both drafting passes correlated closely with cotton stickiness. The breakage rate, expressed for 100 km of sliver, increased with cotton stickiness. The correlation was closer for the number of H2SD sticky points than for trehalulose and melezitose levels. Figure C-24 shows breakage during the first drafting pass plotted against the number of H2SD sticky points (Equation C-3). Similar results were obtained during the second drafting pass.

$$\text{Drawing-breakage} = 0.68 + 0.02675 (\text{H2SD})^2$$

(Equation C-3)

As far as efficiency is concerned, although a significant negative correlation was obtained with the number of H2SD sticky points and the level of trehalulose, the correlation was not as clear as for breakage. Figure C-25 shows the efficiency noted during the second drafting pass as a function of H2SD count. The dispersion of the values is excessively high for any prediction of efficiency based on stickiness. Thus, equation B-4 should be considered simply as a general trend.

$$\text{Drawing-EFF.\%} = 79.7 - 0.875 \text{ H2SD}$$

(Equation C-4)

This dispersion may be explained by the relatively short drawing time used for each test. Here, at 400 m/min, the processing of each test sliver lasted from 1.5 hours for the slightly sticky cottons to 2.5 hours for the most sticky cottons. The effects of machine stoppages is therefore excessive under such conditions and induces considerable variability into the efficiency results.

C.1.3.8. Roving frame

The roving frame is extremely sensitive to stickiness. In the course of the tests the fibers could be seen to rise upwards because of small beads of sugar clearly visible on the drafting rollers and on the aprons. This phenomenon occurred even with cottons that were only very

slightly sticky. The number of breaks was closely correlated to stickiness. Significant correlation coefficients were noted with the number of H2SD and SCT sticky points, and with the trehalulose and melezitose levels. The closest correlation ($r = 0.79$) was obtained using a quadratic model (Equation C-5) linking the number of H2SD sticky points to total breakage in 100 km of roving (Figure C-26).

$$\text{Breakage 100 km roving} = 1.57 + 0.0195 (H2SD)^2 \quad (\text{Equation C-5})$$

Efficiency also correlated well with the number of sticky points and with the trehalulose and sucrose levels. Figure C-27 shows a substantial fall in efficiency correlated with the number of H2SD sticky points. The H2SD number of sticky spots is the most reliable marker of roving frame efficiency ($r = 0.76$). The equation of the best regression found is:

$$\text{Roving-EFF.}\% = 100 - 13.88 (H2SD)^{1/2} \quad (\text{Equation C-6})$$

C.1.3.9. Ring spinning frame

The breakage incidence for 1000 spindle positions hour showed a good correlation with stickiness. The number of H2SD sticky points gave the closest correlation with an r value of 0.82. Although the sugar levels determined by HPLC showed a good correlation with breakage rate, this correlation was lower than that provided by the number of sticky points. Here, the trehalulose and melezitose levels gave an r value of only 0.68. Figure C-28 plots the number of breaks for 1000 spindle positions hour against the H2SD number of sticky points. The y-intercept at the origin is not significantly different from 0.

$$\text{Breakage 1000 s.p.h} = -29.7 + 11.38 H2SD \quad (\text{Equation C-7})$$

C.1.3.10. Open-End rotor spinning frame

The efficiency of the rotor spinning frame decreased as stickiness increased. The closest correlation coefficients were obtained with the H2SD and SCT sticky points counts rather than with the sugar levels determined by HPLC. Here, the correlation coefficients were approximately 0.67 for H2SD whereas they did not exceed 0.64 for the best sugar marker (trehalulose). Efficiency for a non-sticky cotton was about 98%, but this fell to 90% for stickiness exceeding 30 H2SD points. Efficiency can be far lower if clogging occurs, as illustrated by the cotton in Figure C-29 outside the cluster of points. The values predicted by the number of H2SD points again showed a moderate dispersion.

$$\text{OE-EFF.}\% = 98.3 - 0.134 H2SD \quad (\text{Equation C-8})$$

The number of yarn piecings was monitored in addition to machine efficiency. Figure C-30 shows that the number of piecings per hour for 240 spinning positions increased with the number of H2SD points, giving a significant correlation between these two variables with $r = 0.74$.

$$(\text{OE Y-P 240 s.p.h})^{1/2} = 5.19 + 1.429 (H2SD)^{1/2} \quad (\text{Equation C-9})$$

After making three attempts to re-attach the yarn, the machine abandons the process and alerts the operator that intervention is necessary at the stopped spinning position. The number of interventions by the technician hourly is thus a reliable indicator of rotor spinning productivity. These interventions general consist of cleaning the feed table and the breaker or the rotor to remove sticky deposits. The results of the tests conducted here showed that the hourly intervention rate due to clogging for 240 positions is dependent upon the stickiness of the cotton. Whereas the number of interventions was very low for non-sticky cottons, interventions exceeded the threshold of 3/hour when spinning cottons with more than 20 H2SD sticky points.

The models used in this study to predict productivity parameters were based on the results of stickiness measurements. In an effort to improve these models, we added different variables to the H2SD count but all these attempts were inconclusive. When variables concerning the size of the sticky points were added, this did not improve the models, and neither did the addition of sugar levels determined by HPLC, even when the tests were based on different combinations, e.g. the sum of the trehalulose and melizitose entomological sugars. All the models tested showed that only a single variable was significant. This effect is due to the close correlation between the H2SD and SCT sticky points counts and certain sugars, notably trehalulose and melezitose.

The results obtained showed that the number of sticky points measured by the H2SD is more closely correlated to spinning productivity parameters than the SCT and HPLC results. The H2SD count provides the best prediction of breakage rate and spinning machine efficiency. However, the dispersion of the results may occasionally be too great for practical predictions. This is due to the fact that the confidence intervals around the values determined from the regression curve of the H2SD sticky points are relatively broad for certain machines. The prediction method cannot differentiate between two cottons showing fairly similar stickiness potentials. It is therefore difficult to predict different efficiencies or breakage rates for cottons whose stickiness potentials are similar to within 2 or 3 sticky points. Nonetheless, if the precision of the results is taken into account, certain limits can be set for stickiness with respect to the acceptable number of breakage and the efficiency desired during spinning. In our tests, and under the relative humidity conditions used, the stickiness limits for a highly automated production unit would appear to be fairly low, particularly for ring spinning, since the roving frame is highly sensitive to stickiness.

C.1.4. Conditions and operating methods to study the effect of stickiness on yarn quality

In addition, productivity parameters were noted and samples of cotton-fibers, waste, sliver, roving and yarn were taken to evaluate and monitor product quality at each step in the spinning process.

The regularity of the sliver on the card and the drawing frame was evaluated by two measurements of the mass variation (CV%) using an USTER® TESTER3. The roving was evaluated on 4 spindles of the roving frame for each doffing.

On the ring spinning frame, each doffing was 10% sampled, i.e. one bobbin out of 10. These samples of ring-spun yarn were tested on USTER® TESTER3 and USTER® TENSORAPID3 to evaluate the spindle-by-spindle quality for each doffing. The principal characteristics measured consisted of:

- mass variation: Um%, CV%
- imperfections: thin places (-50%), thick places (+50%) and neps

- hairiness: H
- tensile properties: tenacity, elongation and work-to-break.

The same analyses were then repeated for packages of rotor-spun yarn, with a sampling frequency of 4 packages per section of 24 spinning positions daily.

The evaluation of product imperfections was completed by an analysis of CLASSIMAT defects on the packages of rotor-spun yarn and on the non-cleared packages of ring-spun yarn of the winder.

The effects of stickiness on the quality of spun products was evaluated by comparing these different characteristics with the stickiness results obtained in the corresponding cotton fiber samples. Stickiness results were generated by measuring the number of sticky points on the SCT thermodetector and the H2SD *High Speed Stickiness Detector* (Frydrych, 1998) and by using HPLC (*High Performance Liquid Chromatography*) to determine the sugar content of the fiber: Inositol (I), Trehalose (T), Glucose (G), Fructose (F), Trehalulose (W), Melezitose (M) and Sucrose (S). The results presented for these stickiness-predicting results correspond to the mean of the values determined for 10 samples taken from each bale that underwent processing.

C.1.4.1. Results and Discussion: effect on quality

The closest correlation between the quality criteria and the stickiness measurements was obtained for the H2SD number of sticky points. Here, the correlation obtained was not significantly improved when the size of the sticky points was taken into consideration. The sugar content determined by HPLC did not show such a close correlation with the quality criteria. Thus, the rest of this paper is restricted to an examination of the relationship between H2SD stickiness measurements and the different quality characteristics. Note that due to its low UHML, bale AS01 was not considered in the correlation data analysis.

C.1.4.1.1. *Sliver and roving quality*

No significant correlation could be established between the mass variation and the stickiness results on the card or the drawing frame. It was only from the roving frame onward that stickiness had an impact on product quality. The roving regularity was then seen to deteriorate as stickiness increased. Figure C-31 shows a significant correlation between the coefficient of variation of roving mass (CV%) and the H2SD number of sticky points.

C.1.4.1.2. *Ring Spun Yarn quality*

The quality of ring-spun yarn also deteriorated as stickiness increased. Here, yarn regularity, imperfections and certain tensile properties were affected by stickiness.

Figure C-32 shows CV% of yarn mass plotted against the number of H2SD sticky points. The relation is highly significant ($r = 0.80$), with a linear relationship between CV% and H2SD sticky points:

$$RSF-CV\% = 17.3 + 0.548 (H2SD)^{1/2}$$

(Equation C-10)

In this equation, when the cotton is slightly sticky (below 10 H2SD points), the CV% does not exceed 19%, i.e. a value that is within the CV% range noted by 95% of spinners world-wide (USTER[®] STATISTICS 1997).

The number of imperfections per km of yarn also showed a significant correlation with

stickiness. Here, the number of thin places (-50%), thick places (+50%) and neps (+200%) increased with the number of sticky points.

Figure C-33 shows the relationship between the number of thin places and the number of H2SD sticky points. This relation ship is represented by the model given hereafter:

$$RSF\text{-}Thin(-50\%) = 19.8 + 50.19 (H2SD)^{1/2}$$

(Equation C-11)

According to this model, the threshold of 100 thin places/km of yarn, i.e. the value noted by 95% of spinners world-wide (USTER[®] STATISTICS 1997) is exceeded even with very low sticky cotton.

The correlation was even closer for the number of thick places (Figure C-34). Here, with a correlation coefficient of 0.82, the model describing the increase in the number of thick places is more precise. The following equation shows that stickiness must not exceed 10 H2SD points if the spinner wishes to remain below the thick places threshold of 800/km of yarn (95% of spinners according to USTER[®] Statistics 1997).

$$RSF\text{-}Thick (+50\%) = 653.8 + 15.13 H2SD$$

(Equation C-12)

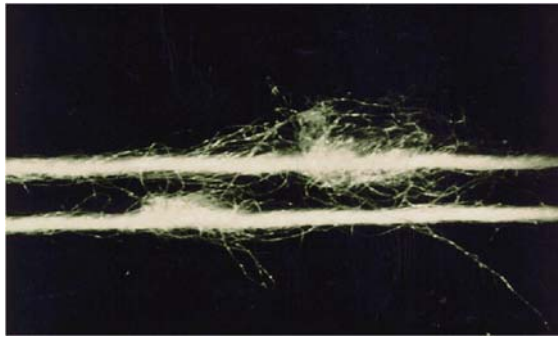
As already seen for thick places, the number of neps was closely correlated to stickiness ($r = 0.84$). The relationship given shows clearly the considerable number of these defects in yarn produced using very sticky cotton (Figure C-35).

$$RSF\text{-}Neps = 680.7 + 19.74 H2SD$$

(Equation C-13)

As seen above, the number of neps per 1000 m of yarn increases with stickiness. Since different types of neps exist in the UT3 detected neps, a detailed analysis (description in the description of output 2.1) of the yarn was conducted on yarn samples. This method stops the evenness tester at each of the detected neps. Then, using a magnifying glass, the nep can be placed in one of 5 categories:

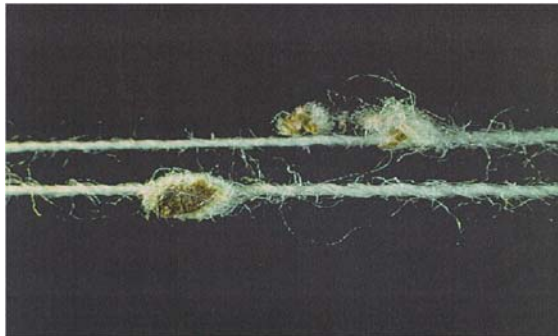
- fiber neps mainly due to immature fibers (Slide C-1)
- seed coat fragments that are part of the seed coat torn off during the ginning process (Slide C-2)
- sticky neps due to honeydew droplets (Slide C-3)
- neps due to entanglements of fibers on a long part of yarn (Slide C-4)
- neps due to other impurities such as leaves, bark ...(Slide C-5)



Slide C-1: Fiber neps.



Slide C-4: Entanglement of fibers.



Slide C-2: Seed coat fragment.



Slide C-5: Bark considered as neps.



Slide C-3: Sticky neps.

On the basis of the results of this detailed analysis, the different neps were classified as shown in Figure C-36. In this chart, cottons were ranked by increasing H2SD stickiness. An increasing number of neps were due to stickiness as the stickiness of the bales increased. A comparable comment is valid for fiber neps.

Table C-12 gives the correlation coefficients between the different nep classes and stickiness, thus expressing stickiness in terms of neps.

Table C-12: Correlation coefficients between H2SD counts and nep classes in RS yarns.

Variable	Correlation coefficient
% neps – SCF	-0.317 NS
% neps – fibers	0.0473 NS
% neps – entanglement	0.0008 NS
% neps – sticky	0.7634 ***
% neps – miscellaneous	0.3668 NS
Nb neps – SCF	0.3710 NS
Nb neps – fibers	0.6847 ***
Nb neps – entanglement	0.2141 NS
Nb neps – sticky	0.7849 ***
Nb neps – miscellaneous	0.3891 NS

NS: non significant at a 5% risk; ***: significant at a 0.1% risk.

The number of sticky neps ('Nb neps – sticky', Figure C-37) and its proportion as a percentage of the total number of neps ('% neps – sticky') are closely correlated to the H2SD count. These relations are expressed in the following formulas:

$$Nb\ neps - sticky = 0.86 + 0.087 \cdot (H2SD)^2$$

$$\% \ neps - sticky = -1 + 0.221 \cdot H2SD$$

(Equation C-14)

The offsets of these equation are not different from 0 and the number of sticky neps increased as the stickiness of the fibers increased.

Concerning fiber neps, the increase in their number was significant (Figure C-38).

The number of SCF, entanglements and neps of diverse origins were not related to stickiness (Figure C-39 to Figure C-41).

Thus, thanks to the detailed analysis, we can confirm that stickiness induces an increase in the total number of neps in the yarn, mainly due to an increase in the number of sticky neps and fiber neps.

The hairiness of ring-spun yarn correlated poorly with stickiness ($r = 0.52$ significant at 1%). However, hairiness was correlated with the number of H2SD sticky points (Figure C-42). The regression obtained is given in the equation below.

$$RSF-H = 6.3 + 0.266 (H2SD)^{1/2}$$

(Equation C-15)

When considering tensile properties, only yarn strength and work-to-break correlated with stickiness. No significant relation was found between stickiness and yarn elongation. By contrast, tenacity and work-to-break fell substantially as the number of H2SD sticky points increased (Figure C-43). Although the correlation coefficients are fairly low, $r = -0.57$ for tenacity and -0.46 for work-to-break, the decrease in these two parameters was nevertheless significant.

$$(RSF-Tenacity)^{1/2} = 3.75 - 0.0531 (H2SD)^{1/2}$$

(Equation C-16)

Figure C-44 shows the relationship between yarn work-to-break and the number of H2SD sticky points, with considerable dispersion of the results.

$$(RS-work)^{1/2} = 2 - 0.0362 (H2SD)^{1/2}$$

(Equation C-17)

C.1.4.1.3. Rotor Spun Yarn quality

Unlike ring-spun yarn, the quality of rotor-spun yarn was little affected by stickiness. The only significant correlation coefficients found concerned tenacity and hairiness. The other variables were unaffected by stickiness. In fact, we even noted a decrease in the number of imperfections as stickiness increased, which can be explained by the micronaire. Here, paradoxically, the CV of yarn mass, the number of thin places, the number of thick places and the number of neps showed a negative correlation with the number of H2SD sticky points. To explain this, we sought to determine which fiber characteristics correlated with stickiness and could explain this effect.

The conclusion that stickiness does not increase the number of imperfections in rotor-spun yarn, unlike ring-spun yarn, was confirmed by the results of the CLASSIMAT[®] defects analysis. In short, most of the defects noted in ring-spun yarn were related to stickiness whereas no significant relationship could be found between open-end yarn defects and stickiness.

The hairiness of open-end yarn increased slightly with stickiness, i.e. a weak correlation ($r=0.48$) was noted between the number of H2SD sticky points and hairiness. This increase was nevertheless perfectly clear (Figure C-45) and the values recorded ranged between 5 and 6.

The tenacity of open-end yarn also showed a significant correlation with the number of H2SD sticky points. Equation 8, which represents the model of the linear variation, shows a gradual reduction in tenacity as the number of H2SD sticky points increases (Figure C-46). The slope is fairly gentle (0.03) but significantly different from 0.

$$OE-Tenacity = 9.2 - 0.03 H2SD$$

(Equation C-18)

In the same manner as for tenacity, the work-to-break of open-end yarn correlated with stickiness. This decreased slightly as the number of H2SD sticky points increased.

No correlation was observed for elongation.

C.1.5. Effects of stickiness on CLASSIMAT[®] defects

This paragraph describes ring spun yarn and open end yarn from a commercial standpoint. Yarns were cleared on a winder set to average parameters to eliminate the largest defects while keeping the winder productive. It is important to note that even the OE yarn was cleared since the automatic controlling system on the OE machine was turned off to avoid breakages due to this quality control system, and thus avoid bias in the evaluation of productivity parameters.

Defects were classified depending on the importance of their mass variation and their length. For each class, the number of defects was expressed per km of yarn.

Table C-13 shows that most of the CLASSIMAT[®] defects in RS yarn were stickiness-dependent, while no correlation was observed for the OE yarns. Indeed, with the exception of classes *D1*, *D4*, *E*, *F* and *G*, the number of defects in ring spun yarns increased with the H2SD count.

Table C-13: Correlation coefficients between CLASSIMAT[®] defects and H2SD count.

Defect	Ring spun yarns		Open-end yarns	
Class	Correlation Coef	Prob. Signi.	Correlation coef	Prob. Signi.
	R	P(x>r)	R	P(x>r)
A1	0.8227	0.0000	-0.1405	0.5224
B1	0.8207	0.0000	0.1356	0.5374
C1	0.4818	0.0232	0.0533	0.8090
D1	0.3064	0.1654	0.0304	0.8906
A2	0.7457	0.0001	0.1096	0.6187
B2	0.8613	0.0000	0.1512	0.4912
C2	0.8046	0.0000	0.0634	0.7737
D2	0.5496	0.0081	-0.1450	0.5090
A3	0.6304	0.0017	0.1603	0.4651
B3	0.8450	0.0000	0.1761	0.4216
C3	0.7500	0.0001	0.1822	0.4053
D3	0.4504	0.0354	-0.1932	0.3770
A4	0.4672	0.0284	0.1217	0.5801
B4	0.6106	0.0025	0.0355	0.8722
C4	0.5310	0.0110	-0.1554	0.4790
D4	0.3833	0.0783	-0.3089	0.1516
E	0.1018	0.6523	0.1662	0.4484
F	0.1113	0.6218	0.2108	0.3343
G	-0.0586	0.7956	0.0998	0.6506
H1	0.7222	0.0001	0.2066	0.3442
I1	0.4762	0.0251	0.1466	0.5046
H2	0.7651	0.0000	-0.1451	0.5089
I2	0.4868	0.0216	0.0251	0.9096

Results are given below for the most significant relations between the number of yarn defects and H2SD sticky points (thick places *A4*, *B3*, *B4*, *C2*, *C3*, *C4*, *D1*, *D2*, *D3*, *D4*) (Figure C-47 to Figure C-56) and fineness *I1*, *I2*, *H1* and *H2* (Figure C-57 to Figure C-60).

These figures show that the most important Classimat defects in RS yarn increase with H2SD sticky points, in particular thick places +100% and thin places -30%. Defects less than 8 cm in

length (classes E, F and G) do not depend on stickiness because they have probably been cleared in the winding operation.

In conclusion, RS yarn defects increase with stickiness whereas those in OE yarns are unaffected.

C.1.6. Conclusions

C.1.6.1. Effect on productivity

The performance of spinning machines is dependent upon the stickiness of the cotton starting material they use. In this study, machine performance decreased when sticky cottons were processed under the hygrometric conditions generally recommended, i.e. 45 to 50% RH during opening and carding, and 55 to 60% RH during spinning. The effects of the stickiness on machine productivity were quantified. The results of the regressions showed that the number of sticky points determined by H2SD is a more reliable predictor of stickiness effects than the SCT count or the sugar content measured by HPLC. Here, although the SCT count correlates with productivity parameters, the correlation coefficients obtained with H2SD are even better. As far as the sugar contents are concerned, not all correlated with the breakage incidence and machines efficiency. In fact, only trehalulose, melezitose and sucrose could be correlated with these two parameters, but not for all the machines, and here, when a correlation was detected, this was generally no better than that obtained with the H2SD sticky points count.

The blocking threshold for the spinning of sticky cottons under the relative humidity conditions described above was about 50 H2SD sticky points. The spinning process is blocked at the card when the count exceeds this value. In addition, stickiness affects the machines and seriously reduces productivity well below this blocking limit. The roving frame is the most sensitive to stickiness.

The relative humidity appears to be of prime importance. The very sticky bales (50 H2SD sticky points) that initially required machine stoppage were subsequently processed successfully at 40% relative humidity. However, the breakage rate even under these conditions was prohibitively high and machine efficiency was very low. A study to evaluate the effects of stickiness at different relative humidity values is presented in paragraph C.5. Some results are also presented in paragraph C.2.

C.1.6.2. Effect on quality

This study concerning the carded spinning of sticky cottons showed that stickiness has effects both on the productivity and the quality of industrial spinning under the temperature and relative humidity conditions usually recommended. Here, the cotton was prepared and carded at 25 °C and 47.5% RH and was spun at 25 °C and 57.5% RH. These conditions were maintained within ± 2 °C and $\pm 2.5\%$ relative humidity throughout the study.

Although card and drawing frame productivity was reduced by stickiness, this stickiness had no effect on sliver quality at this point. It was only from the roving frame onward that a stickiness-induced decrease in regularity was observed. The CV% of the roving mass was slightly higher, thus increasing the irregularity of the yarn on the ring-spinning frame.

When considering the actual spinning, the quality of ring-spun yarn was more susceptible to stickiness than that of rotor-spun yarn. Monitoring of regularity, imperfections and tensile properties clearly highlighted this difference between the two processes where the CV% of mass, number of thin places, number of thick places and number of neps in the ring-spun yarn

increased significantly with the number of H2SD sticky points. The tensile properties of this ring-spun yarn, and particularly its tenacity and work-to-break capacity, decreased as stickiness increased. By contrast, most of the quality characteristics of the rotor-spun yarn were unaffected by cotton stickiness. Thus, the CV% of mass, the number of thin places, the number of thick places and the number of neps were unrelated to cotton stickiness. Only the tenacity and hairiness of the rotor-spun yarn were affected by the stickiness, i.e. a slight decrease in tenacity and a slight increase in hairiness. The same difference between the two types of yarn was also observed for the number of CLASSIMAT[®] defects.

It has been recognized that relative humidity plays an important role in the effects of stickiness on productivity. By contrast, its impact on the effects of stickiness on yarn quality have not yet been correctly evaluated. A study to evaluate the effects of stickiness at different relative humidity values is presented in paragraph C.5. However, some results are also presented in paragraph C.2.

C.2. Specific experiment at low relative humidity in ITF

C.2.1. Objective

In the experiment described above, it was impossible to process some bales into yarn because of excess stickiness. It was therefore decided to process these bales using the same industrial process but under different ambient conditions to determine the benefit of such a decrease in relative humidity.

C.2.2. Materials and methods

In this experiment, relative humidity was decreased to $38.5 \pm 2.5\%RH$ in all the workshops. Four trials were conducted as follows:

- 2 trials from the blowing room to spinning using bales AR17 and AS15 impossible to process under normal ambient conditions (45-50%RH).
- 2 other trials on the flyer and the ring spinning frame using sliver material from bales AS02 and AS05 obtained during the normal ambient conditions experiment.

This provided 4 data points for the flyer and ring spinning frame, and 2 points for the blowing room to the card. All the settings and sampling procedures were the same as for the normal ambient conditions experiment (described in paragraph C.1.2)

C.2.3. Results

C.2.3.1. Effect at the card level

While it was impossible to process at 47%RH, cotton-spin ability was improved at 38.5%RH. However, the number of breaks was very high (Table C-14).

Even if efficiency was acceptable, the number of breaks was high (30 to 44 breaks per hour for 14 cards).

Table C-14: Spinning results at 2 relative humidities.

Bale	H2SD	SCT	38.5%RH			47.5%RH		
			Nb breaks per 100 km	Efficiency	CV% mass	Nb breaks per 100 km	Efficiency	CV% mass
AS02	37	73	-	-	-	23	75%	4.75
AS05	50	96	-	-	-	27	55%	4.96
AS15	48	39	29	78%	4.54	Impossible to run:		
AR17	47	50	44	85%	4.69	Card saturation		

Decreasing the relative humidity enables sticky cottons to be processed, even if the number of breaks is high.

C.2.3.2. Effect at the drawing frame level

Table C-15 and Table C-16 give the data collected at the 2 steps in drawing frame operations. Although results are available for bales AS02 and AS03 under low humidity conditions, we can deduce a clear improvement in spin ability under low RH conditions. Indeed, the bales used in this experiment were heavily contaminated. Thus if we consider that these 4 bales showed equivalent stickiness (taking account of stickiness variability), the decrease in relative humidity reduced the number of breaks and improved efficiency.

Table C-15: Results of spinning at 2 relative humidities, drawing frame 1st draft.

Bale	H2SD	SCT	38.5%RH			47.5%RH		
			Nb breaks per 100 km	Efficiency	CV% mass	Nb breaks per 100 km	Efficiency	CV% mass
AS02	37	73	-	-	-	37	35%	4.70
AS05	50	96	-	-	-	71	39%	4.33
AS15	48	39	4.03	68%	5.48	No data:		
AR17	47	50	3.79	69%	4.47	Card saturation		

Table C-16: Results of spinning at 2 relative humidities: drawing frame 2nd draft.

Bale	H2SD	SCT	38.5%RH			47.5%RH		
			Nb breaks per 100 km	Efficiency	CV% mass	Nb breaks per 100 km	Efficiency	CV% mass
AS02	37	73	-	-	-	31	19%	4.22
AS05	50	96	-	-	-	56	19%	4.01
AS15	48	39	0	57%	3.87	No data:		
AR17	47	50	18	52%	3.81	card saturation		

C.2.3.3. Effect at the flyer level

Table C-17 shows the results obtained at 38%RH compared to 47%RH at the flyer level.

The decrease in the relative humidity clearly improved the spin ability of sticky cottons on the flyer machine. Indeed, breakages and efficiency were improved by changing the ambient conditions in the workshops. The mass variation of the flyer yarn seemed not to be affected by this change of humidity.

Table C-17: Results of spinning at 2 relative humidities: flyer.

Bale	H2SD	SCT	38.5%RH			47.5%RH		
			Nb breaks per 100 km	Efficiency	CV% mass	Nb breaks per 100 km	Efficiency	CV% mass
AS02	37	73	3.33	75%	7.06	40	10%	7.76
AS05	50	96	3.69	71%	6.94	55	7%	7.83
AS15	48	39	0.54	84%	9.19	No data: card saturation		
AR17	47	50	0.76	66%	7.23			

C.2.3.4. Effect on the ring spinning frame

The humidity of the spinning workshop was lowered from 57.5% RH to 38.5%RH for this experiment. Main productivity and quality parameters were estimated as given in Table C-18

Table C-18: Results of spinning at 2 relative humidities: ring spinning frame.

Bale	H2SD	SCT	38.5%RH					57.5%RH				
			Breaks 1000 s.p.h	CV%	Thin	Thick	Neps	Breaks 1000 s.p.h	CV %	Thin	Thick	Neps
AS02	37	73	109	20.4	57	288	347	485	20.8	236	1353	1586
AS05	50	96	60	20.6	98	336	297	528	21.3	358	1424	1633
AS15	48	39	109	21.6	100	354	374	No data: card saturation				
AR17	47	50	109	19.5	36	261	276					

Decreasing the relative humidity improved the spin ability of the cottons on the ring spinning frame both in terms of productivity and quality. The only unchanged parameter was the evenness CV%.

C.2.3.5. Conclusion

By testing heavily contaminated cottons under conditions of low relative humidity, we demonstrated an improvement in their spin ability. Indeed, heavily contaminated cottons and/or cottons impossible to process under normal conditions were processed into yarn at lower humidity.

While the improvement was slight at the card and drawing-frame levels, it became significant for the flyer and the ring spinning frame.

Decreasing the humidity seems to not affect sliver and flyer yarn quality. On the other hand, it clearly improves yarn quality parameters.

These results are conclusive but need to be confirmed on an extended range of cotton under different humidity conditions (see paragraph C.5).

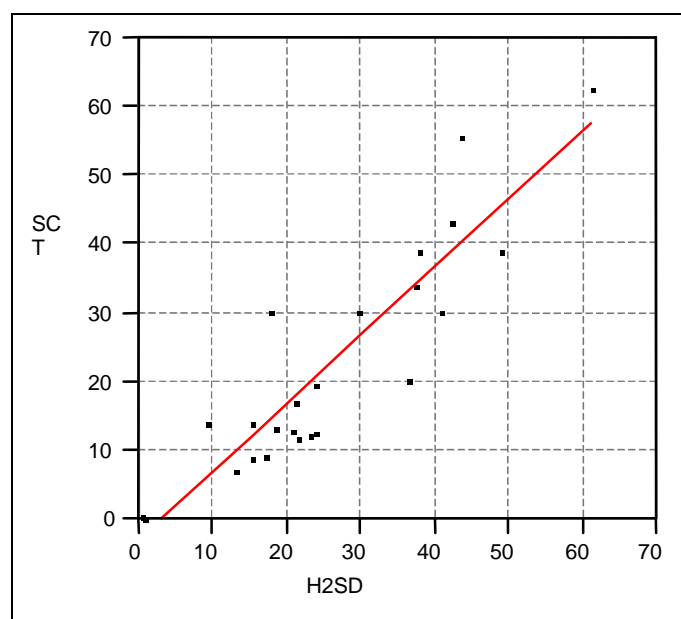


Figure C-13: Relationship between SCT and H2SD counts in raw cottons.

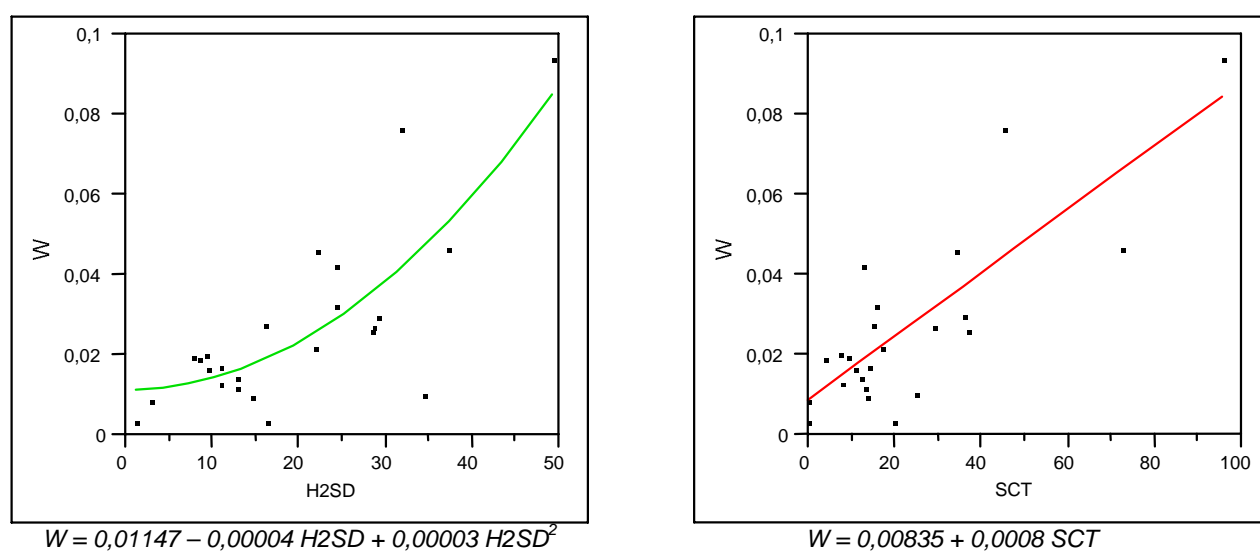
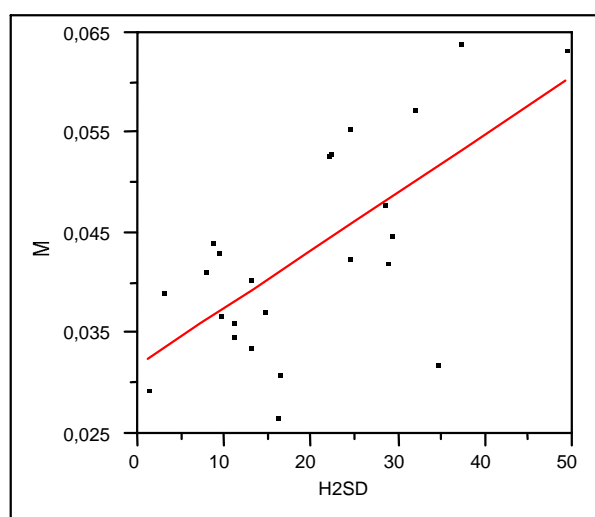
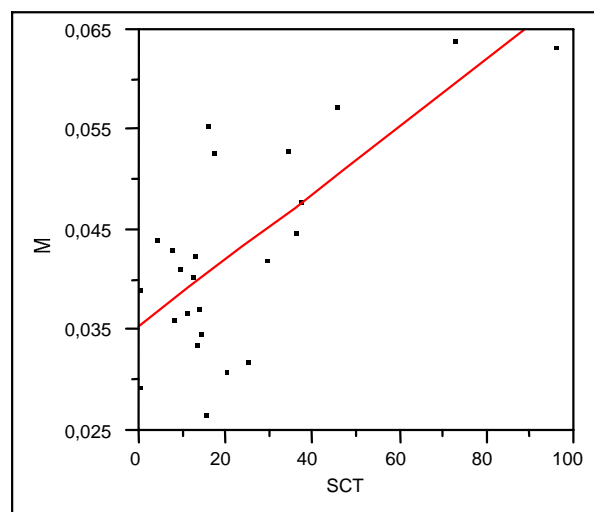


Figure C-14: Trehalulose content (W) plotted against the number of sticky points as measured by H2SD and SCT.

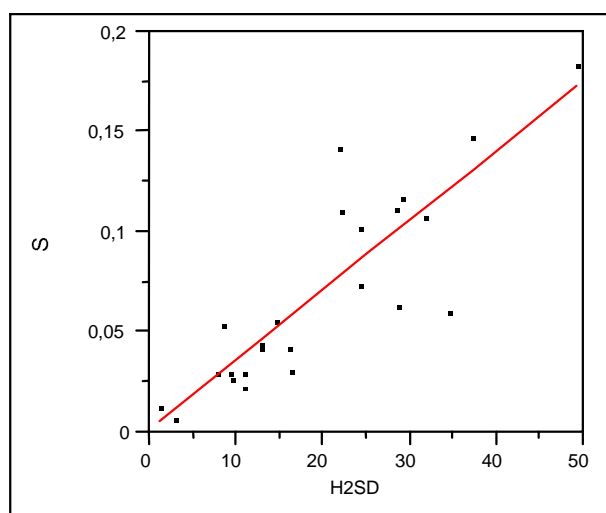


$$M = 0,03173 + 0,00058 \text{ H2SD}$$

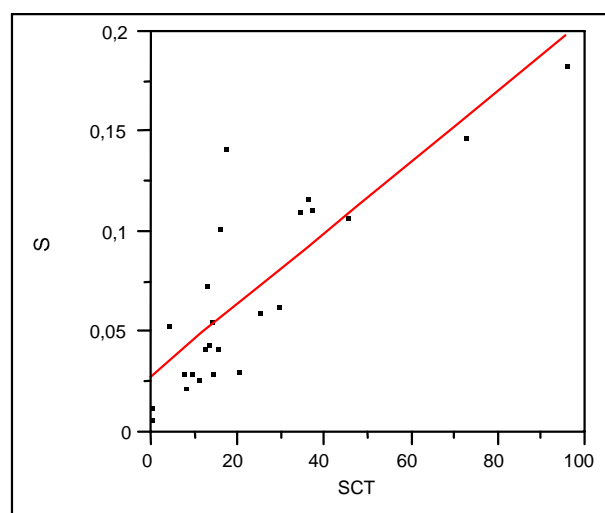


$$M = 0,03534 + 0,00033 \text{ SCT}$$

Figure C-15: Melezitose content (M) plotted against the number of sticky points as measured by H2SD and SCT.

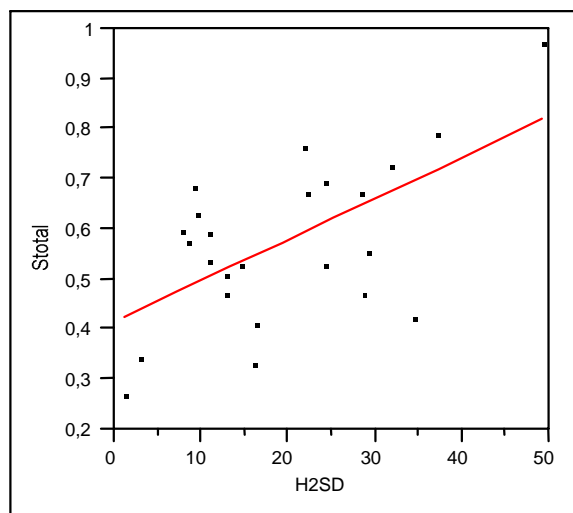


$$S = 0,00103 + 0,00348 \text{ H2SD}$$

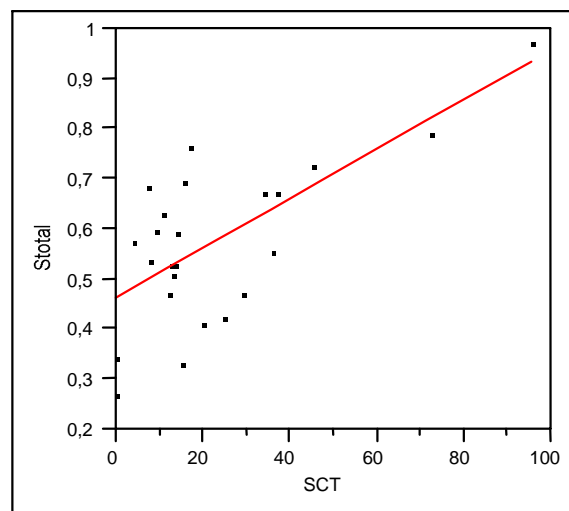


$$S = 0,02805 + 0,00178 \text{ SCT}$$

Figure C-16: Saccharose content (S) plotted against the number of sticky points as measured by H2SD and SCT.



$$Stotal = 0,414 + 0,0082 H2SD$$



$$Stotal = 0,461 + 0,0049 SCT$$

Figure C-17: Total sugars content (*Stotal*) plotted against the number of sticky points as measured by *SCT* and *H2SD*.

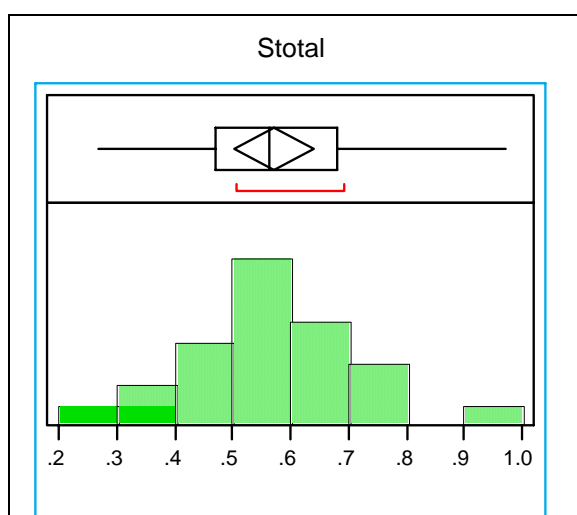


Figure C-18: Total sugar (%w/w) distribution for all cottons.

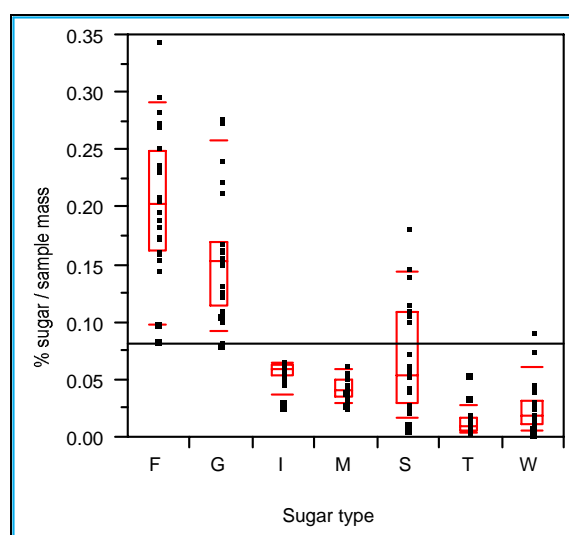


Figure C-19: Distribution of sugar types (%w/sample weight).

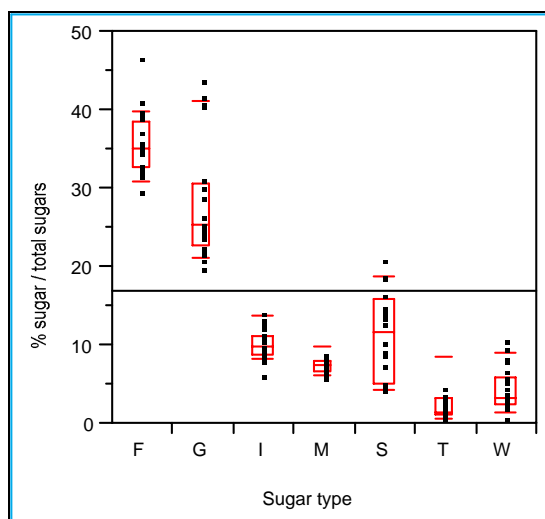


Figure C-20: Sugar content as a proportion of total sugars, without Central Asia cottons.

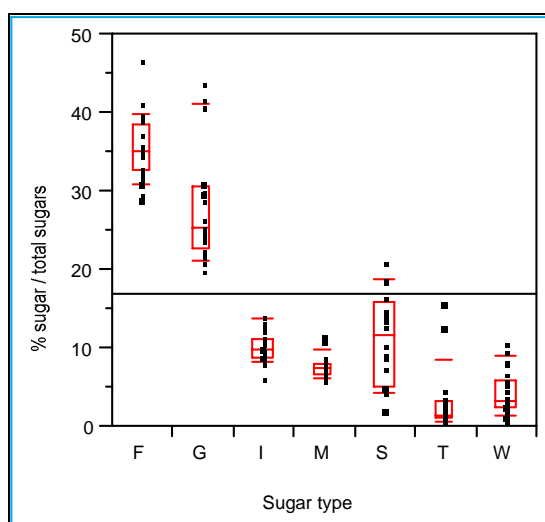


Figure C-21: Sugar content as a proportion of total sugars, with Central Asia cottons.

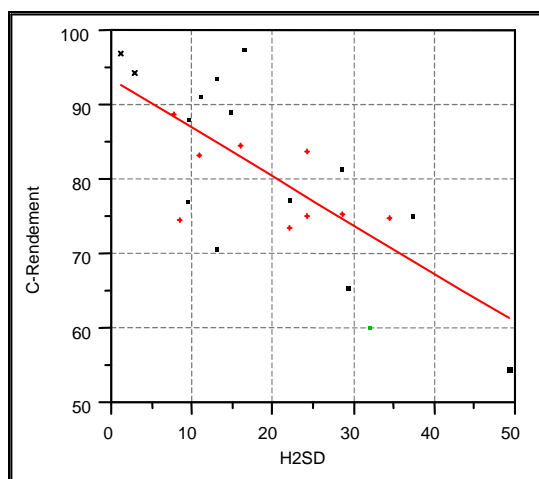


Figure C-22: Card efficiency vs H2SD.

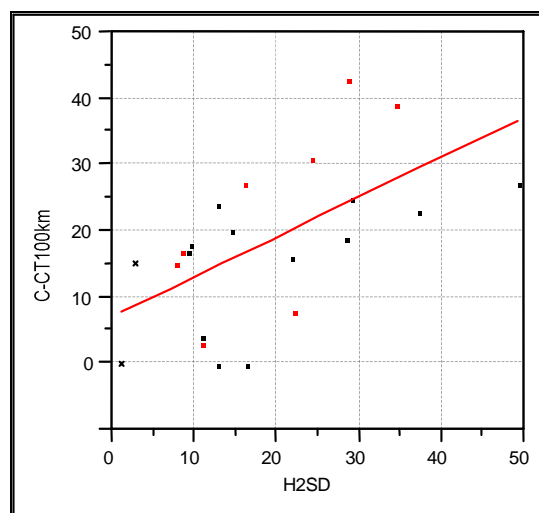


Figure C-23: Total number of breakages per 100 km at the card level vs H2SD.

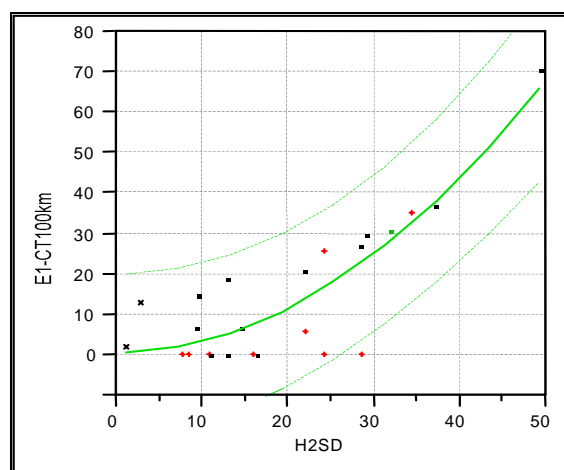


Figure C-24: Total number of breakages per 100 km at the 1st drafting pass vs H2SD.

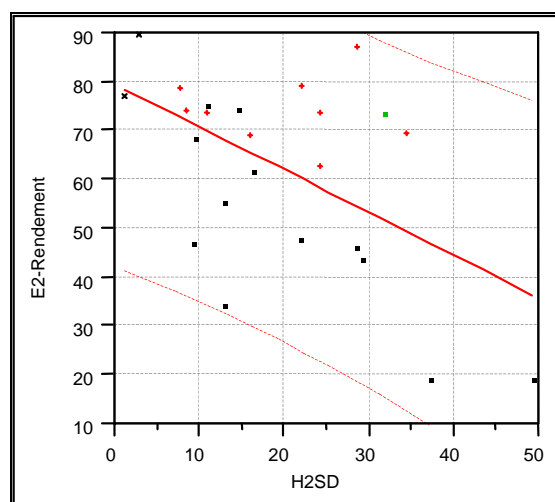


Figure C-25: Drawing frame efficiency (2nd draft) vs H2SD.

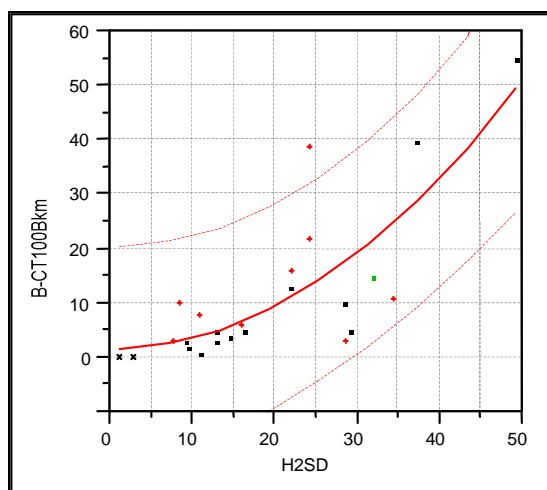


Figure C-26: Total number of breakage per 100 km of roving material at the flyer level vs H2SD.

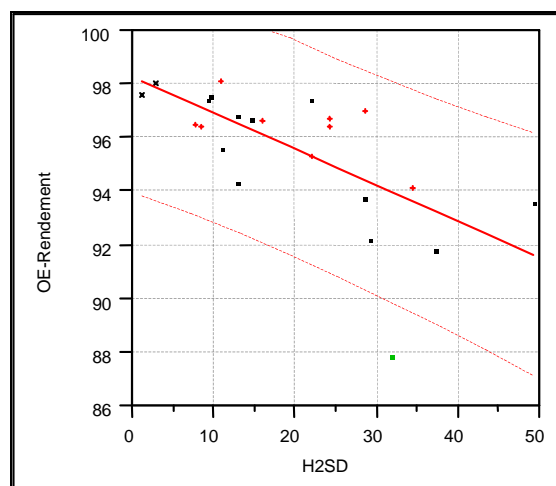


Figure C-29: Open-end efficiency vs H2SD.

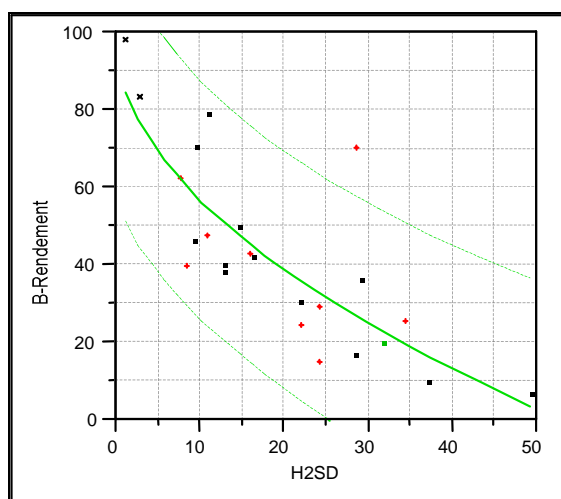


Figure C-27: Flyer efficiency vs H2SD.

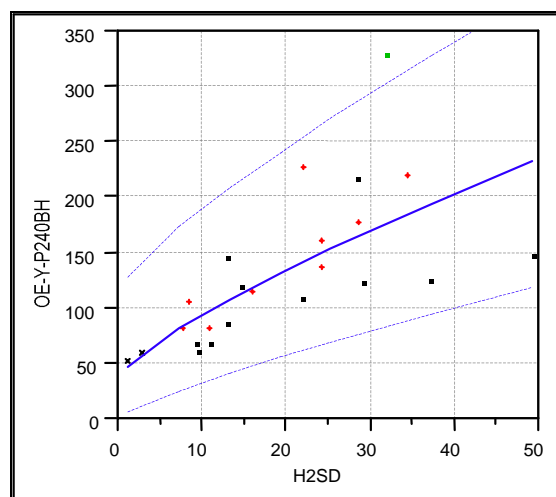


Figure C-30: Number of OE yarn-piecing per 240 rotors/hour vs H2SD.

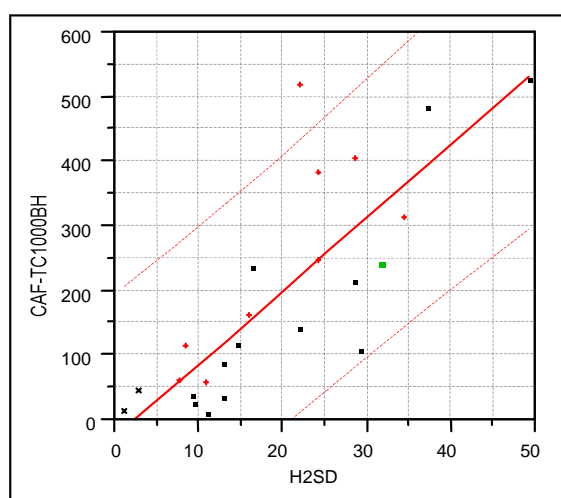


Figure C-28: Ring spinning frame breakage ratio per 1000 spindles/hour vs H2SD.

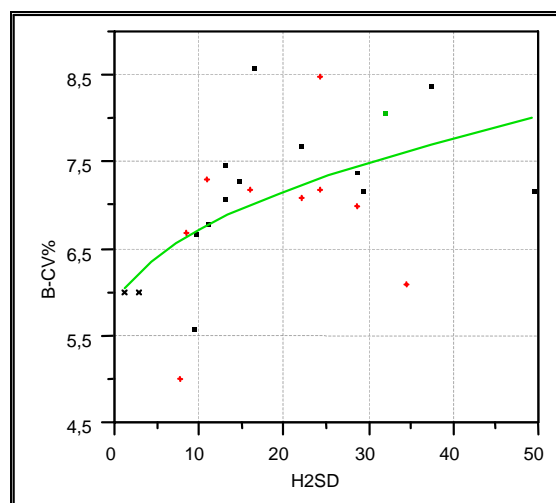


Figure C-31: Mean mass CV% of the flyer fleece vs H2SD.

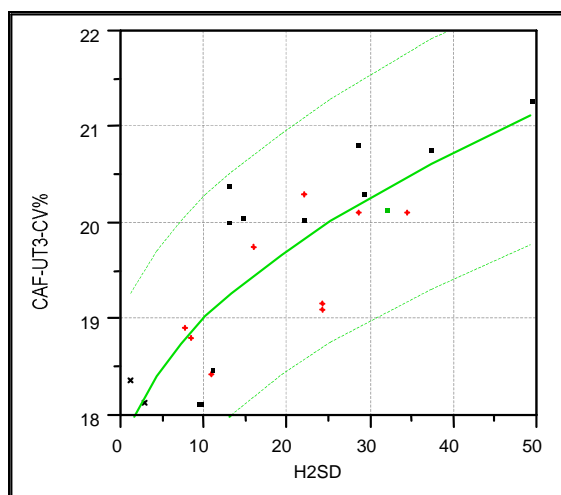


Figure C-32: Mean mass CV% of ring spun yarn vs H2SD.

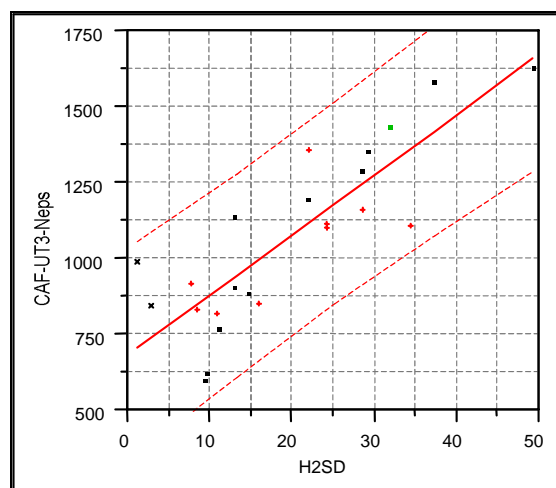


Figure C-35: Number of neps per km of RS yarn vs H2SD.

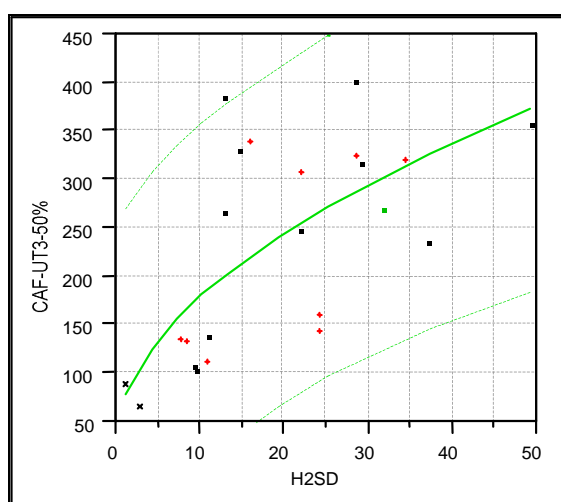


Figure C-33: Number of thin places (-50%) per km of RS yarn vs H2SD.

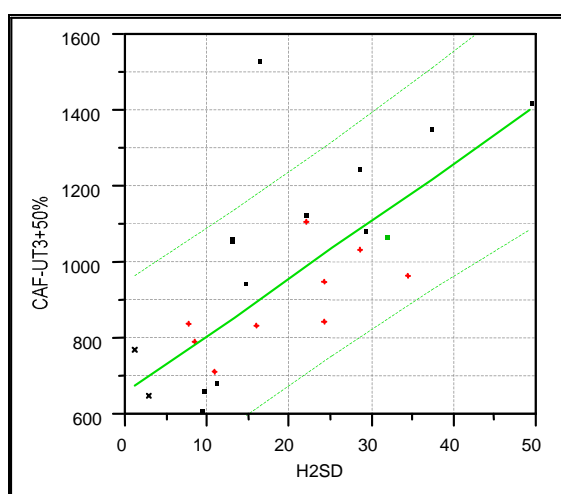


Figure C-34: Number of thick places (+50%) per km of RS yarn vs H2SD.

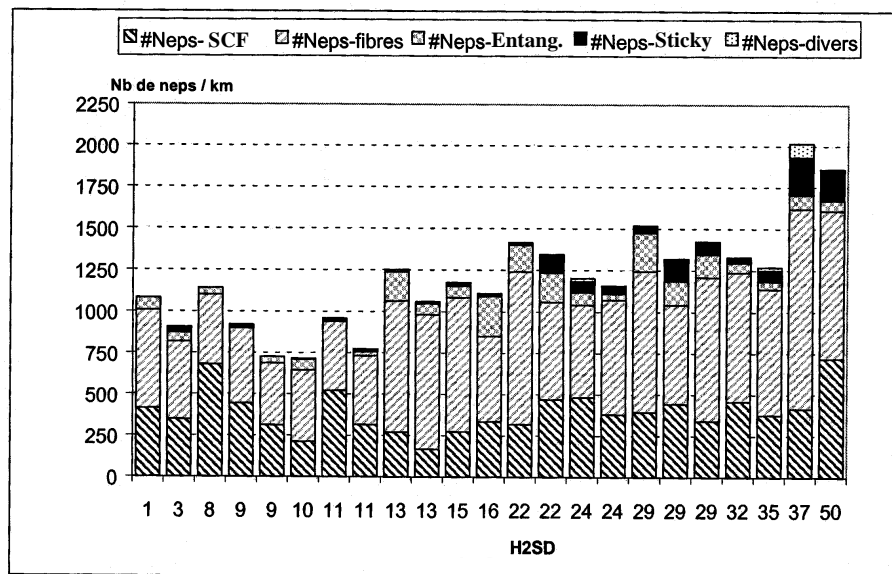


Figure C-36: Distribution in the different nep classes.

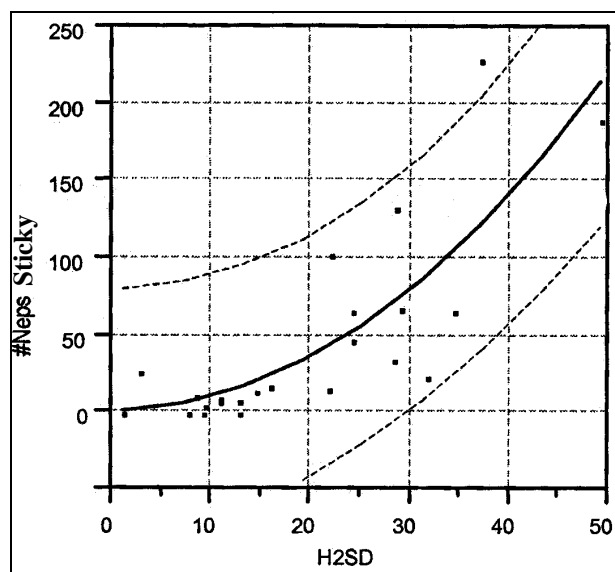


Figure C-37: Number of sticky neps per 1000 m of RS yarn vs H2SD count.

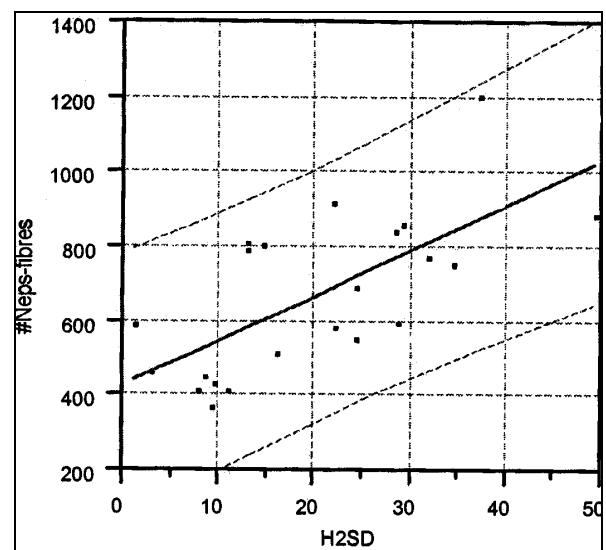


Figure C-38: Number of fiber neps per 1000 m of RS yarn vs H2SD count.

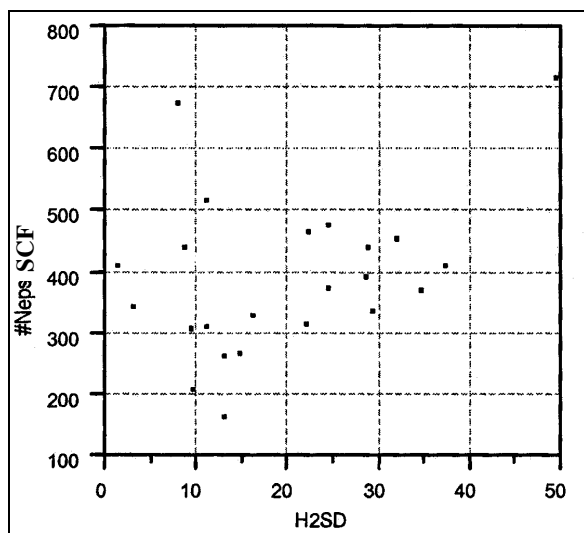


Figure C-39: Number of SCF per 1000 m of RS yarn vs H2SD.

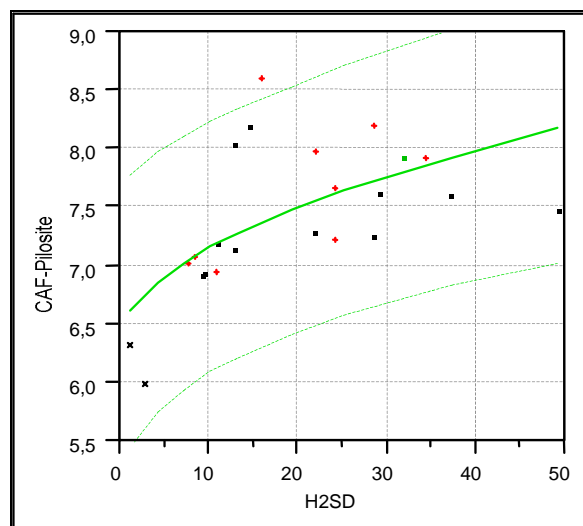


Figure C-42: Hairiness of the RS yarn vs H2SD.

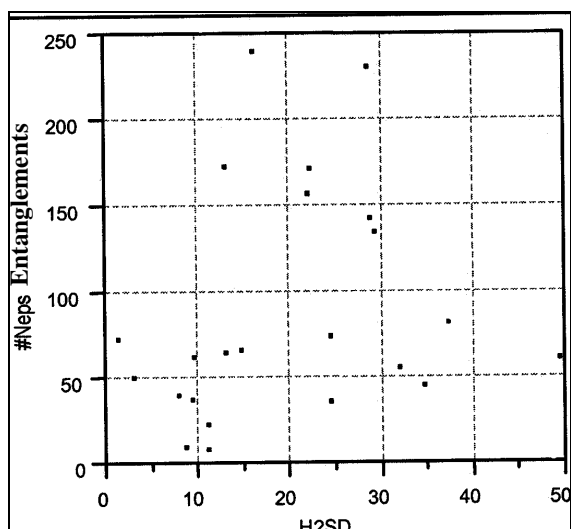


Figure C-40: Number of entanglements per 1000 m of RS yarn vs H2SD.

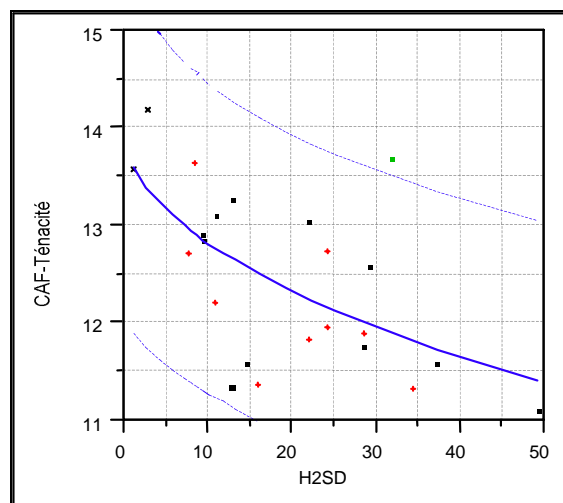


Figure C-43: RS Yarn strength (cN/tex) vs H2SD.

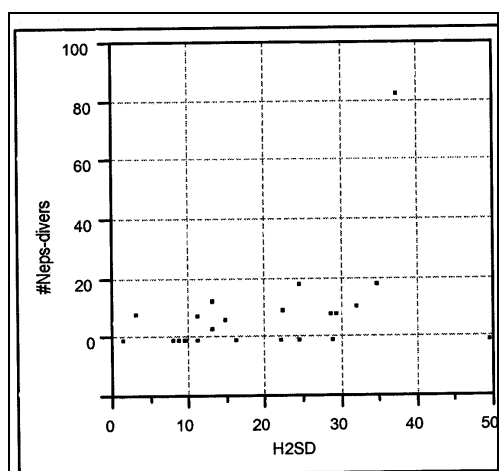


Figure C-41: Number of neps of diverse origins per 1000 m of RS yarn vs H2SD.

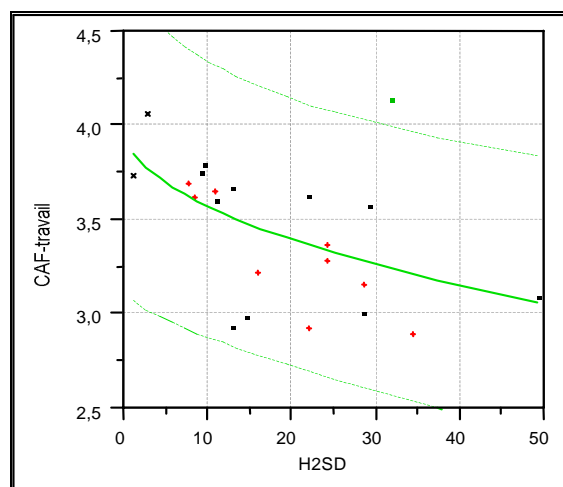


Figure C-44: RS work to break (cN.m) vs H2SD count.

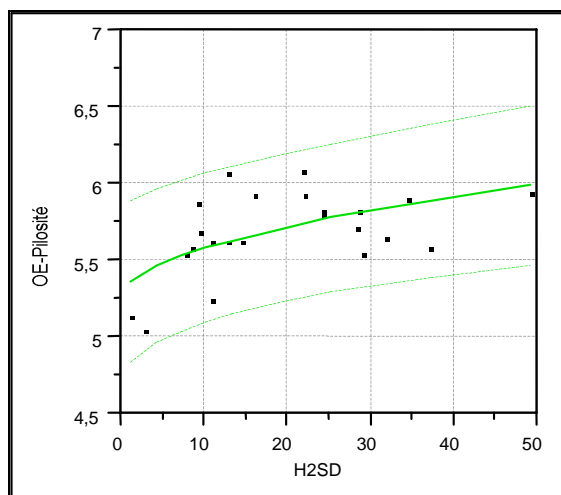


Figure C-45: Hairiness of the OE yarn vs H2SD count.

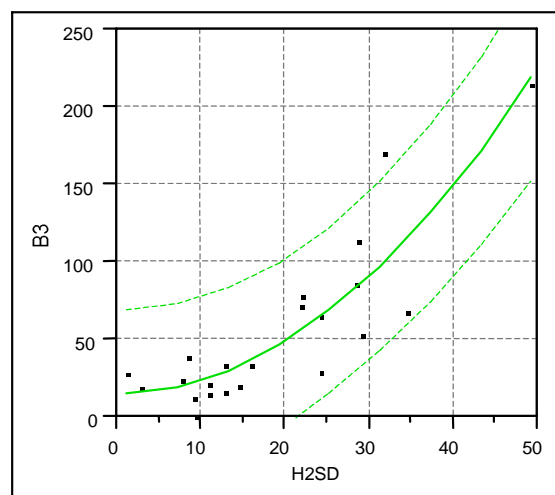


Figure C-48: Number of defects class *B3* per km of RS yarn vs H2SD count.

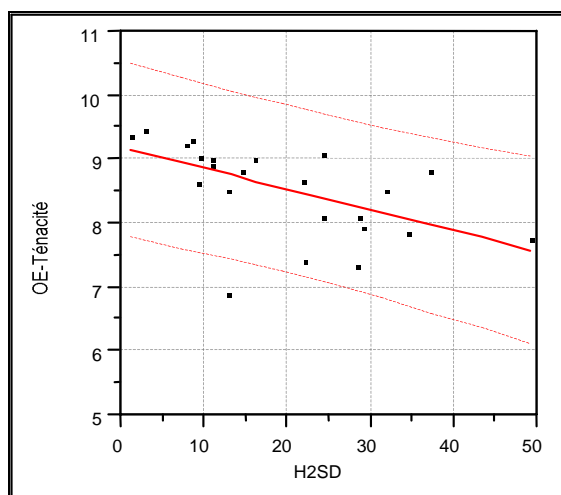


Figure C-46: OE yarn strength (cN/tex) vs H2SD count.

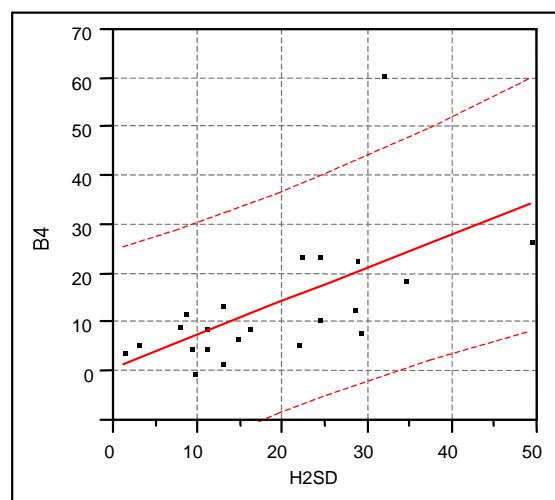


Figure C-49: Number of defects class *B4* per km of RS yarn vs H2SD count.

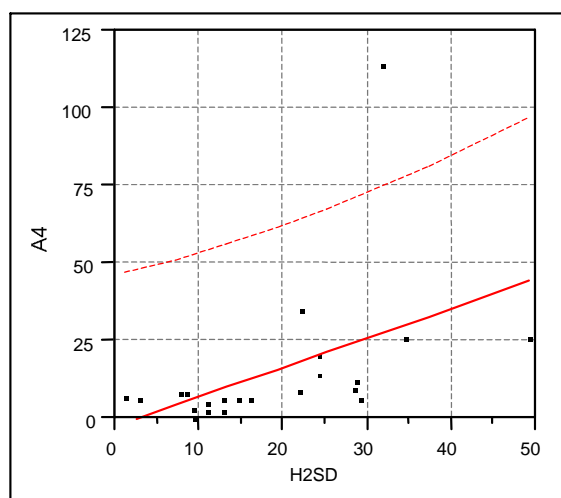


Figure C-47: Number of defects class *A4* per km of RS yarn vs H2SD count.

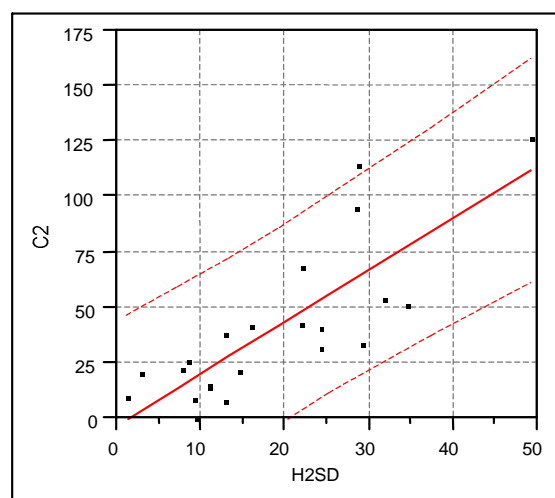


Figure C-50: Number of defects *C2* per km of RS yarn vs H2SD count.

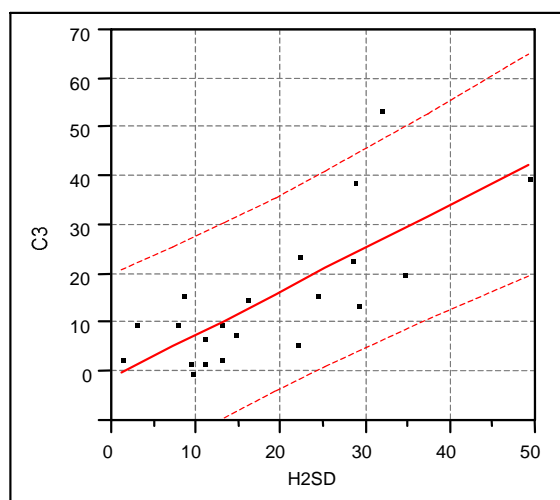


Figure C-51: Number of defects class *C3* per km of RS yarn vs H2SD count.

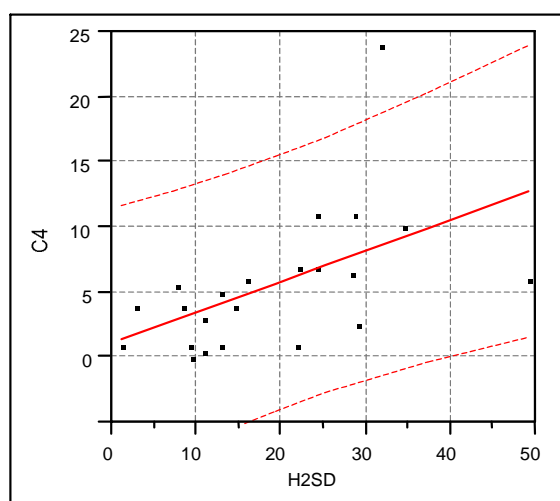


Figure C-52: Number of defects *C4* per km of RS yarn vs H2SD count.

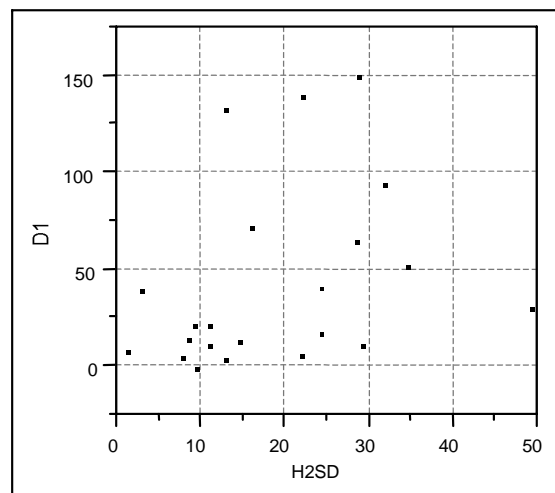


Figure C-53: Number of defects class *D1* per km of RS yarn vs H2SD count.

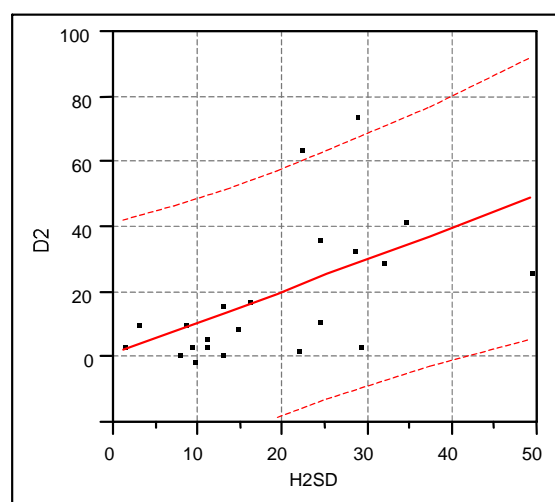


Figure C-54: Number of defects class *D2* per km of RS yarn vs H2SD count .

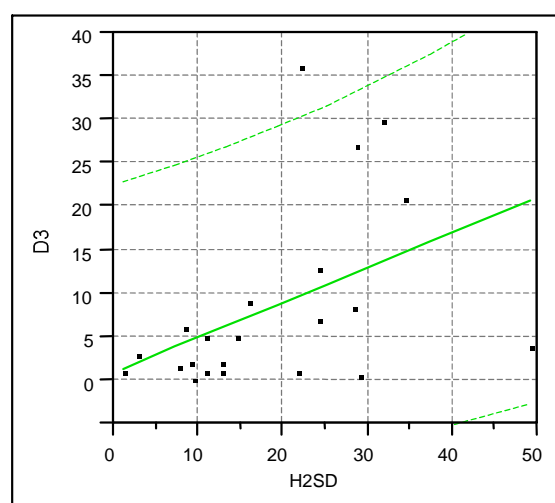


Figure C-55: Number of defects class *D3* per km of RS yarn vs H2SD count.

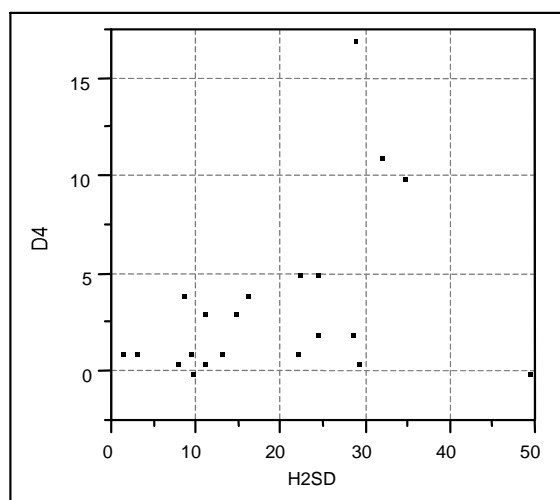


Figure C-56: Number of defects class *D4* per km of RS yarn vs H2SD count.

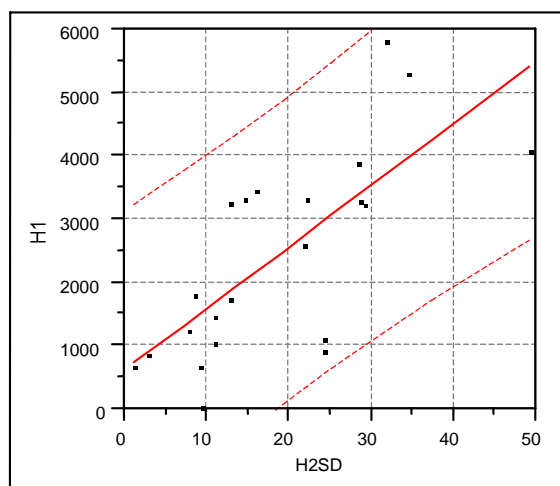


Figure C-57: Number of defects class *H1* per km of RS yarn vs H2SD count.

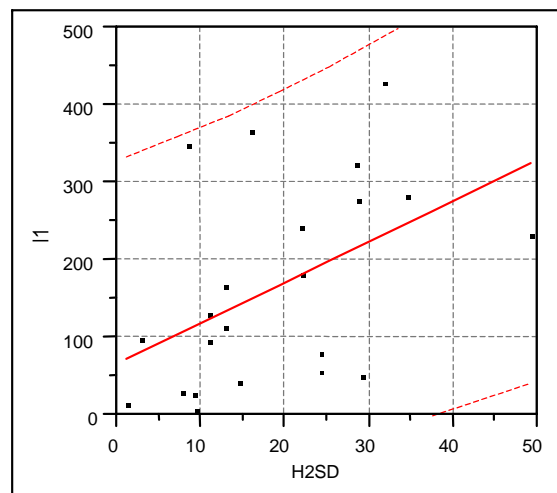


Figure C-58: Number of defects class *H1* per km of RS yarn vs H2SD count.

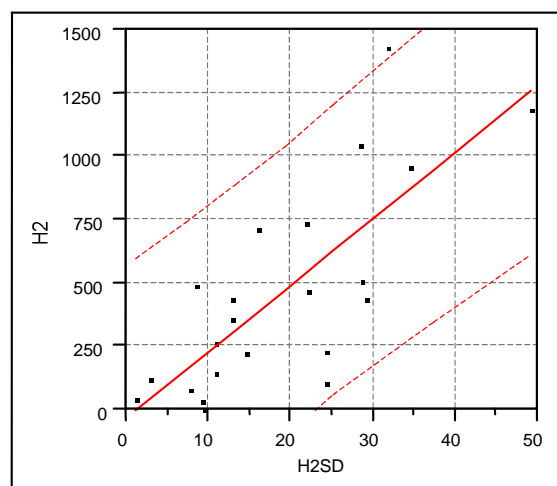


Figure C-59: Number of defects class *H2* per km of RS yarn vs H2SD count.

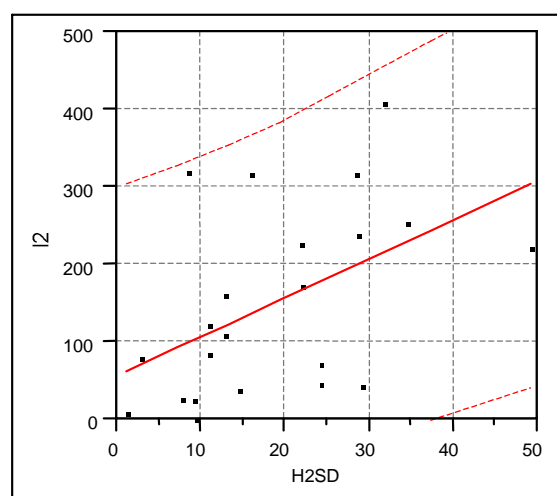


Figure C-60: Number of defects class *I2* per km of RS yarn vs H2SD count.



Slide C-6: Preparation of the bales.



Slide C-7: Bales ready to be processed.



Slide C-8: Laroche bale breaker.



Slide C-9: Blowing room line.



Slide C-10: Cotton fibers are homogenized.



Slide C-11: Zoom on the opener teeth.



Slide C-12: Inside the air transportation pipes .



Slide C-13: Sampling for future quality determinations.



Slide C-14: Cotton at the RN operation.



Slide C-15: Cleaning of the blowing room.



Slide C-16: Cleaning the blowing room.



Slide C-20: Card clothing after a test.



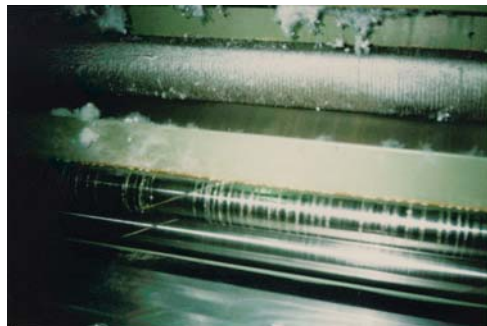
Slide C-17: Carding machine in operation.



Slide C-21: Knives in the carding machine after a test.



Slide C-18: Stopped carding machine.



Slide C-22: Card crushroll after a test.



Slide C-19: Carding machine in operation.



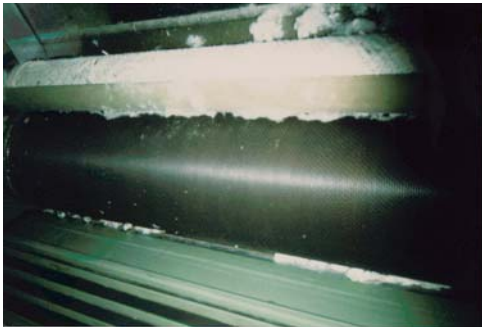
Slide C-23: Cleaning the crushrolls.



Slide C-24: Cleaning the card clothes.



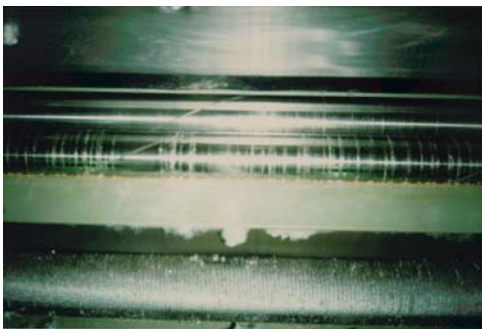
Slide C-28: Break of a card web.



Slide C-25: Card crush-rolls.



Slide C-29: Card and drawing frame room.



Slide C-26: Card crush-rolls.



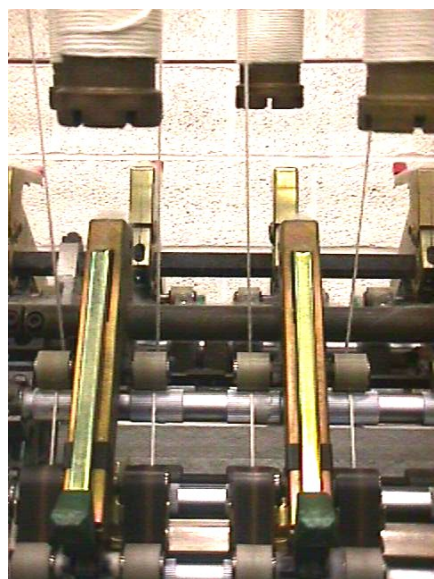
Slide C-27: Break of a card web.



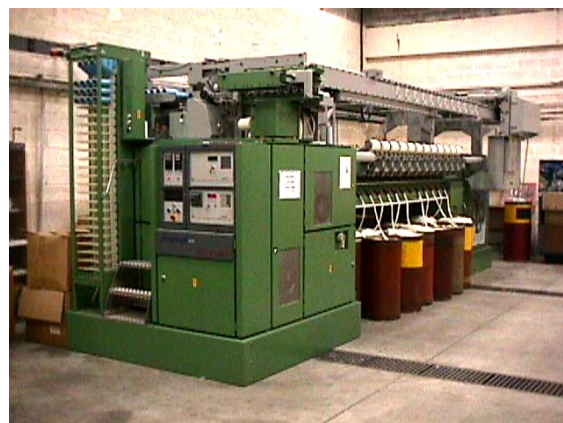
Slide C-30: Flyer.



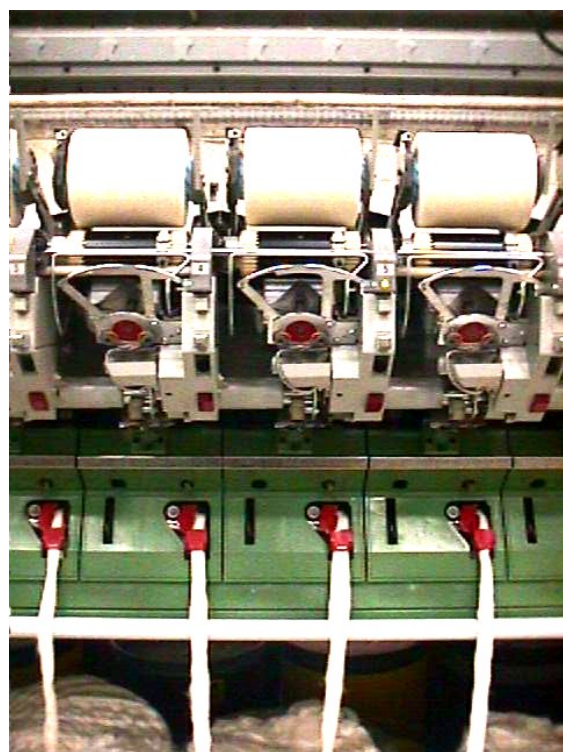
Slide C-31: Ring spinning frame.



Slide C-32: Ring frame drafting zone.



Slide C-33: Open-end machine.



Slide C-34: Open-end spinning positions

C.3. Stickiness effects on the combing process

C.3.1. Objective

This experiment was designed to evaluate the effect of stickiness under specific production conditions used to obtain finer yarn. New equipment is added to the routine production process in order to remove the shortest fibers. To run this operation, it is necessary to individualize cotton fibers, and particular susceptibility to stickiness is foreseen.

C.3.2. Materials and methods

As stated earlier, the Barakat variety used in our combing experiments did not show a wide range of stickiness levels. Thus, only a few bales showed more than 10 SCT sticky points (on raw cottons). Therefore, the effect of stickiness on the combing process cannot be evaluated quantitatively.

We therefore decided to conduct this experiment on only 5 bales (quality parameters given in Table C-19) to obtain a descriptive study of the effect of stickiness.

Table C-19: Quality results for Barakat cottons.

Bale	Ginning*	Variety	ML	UHML	UI%	Strength	Elong.	IM	MR	PM	H	HS	Rd	+B
			Mm	Mm		g/tex	%			%	mtex	mtex	%	
BR12	R	Barakat	28.3	33.8	83.8	36.1	6.3	3.5	0.83	73.8	150	181	68.0	12.7
BR07	R	Barakat	28.4	33.6	84.5	35.7	6.2	3.6	0.84	75.0	154	183	70.7	12.3
BR16	R	Barakat	28.9	34.2	84.6	37.0	6.5	3.4	0.83	73.5	147	178	69.0	12.6
BR03	R	Barakat	29.6	34.8	85.1	38.6	6.8	3.7	0.85	75.5	158	186	67.9	13.1
BR14	R	Barakat	27.5	33.1	83.1	34.7	6.0	3.2	0.78	69.4	141	181	68.8	13.0

C.3.2.1. Steps in the test

The same operations as for carding were retained for the blowing room and card tests .

After homogenizing the fiber by recycling between the Laroche bale-breaker and the RN opener cleaner, each bale was processed as described in Figure C-61.

After this cleaning operation, the cotton was processed to form 5 ktex slivers in the DK 715 card at a production rate of 120 m/min. The slivers then went across the D1/1 drawing frame using a doubling of 6. Cans of slivers were then transferred for a combing process in the 'Caulliez Frères' spinning mill.

The sliver was prepared for combing on a sliver lap machine with 3 heads delivering a fleece of 65 ktex at 80 m/min with a doubling of 36. Fleeces then fed the E7/5 combing machine (8 heads) delivering a 5 ktex sliver at 130 m/min.

After this operation, slivers went on the 2° D1/1 draft auto-regulated drawing frame with a doubling of 8, and were then transformed in 0,5 ktex flyer yarn on F1/1a flyer whose 24 positions operate at 950 rpm. The material was then used to prepare 16.7 tex yarn on a ring spinning frame (100 positions).

The distances between the cylinders in the drafting zones were set according to the length of the fibers.

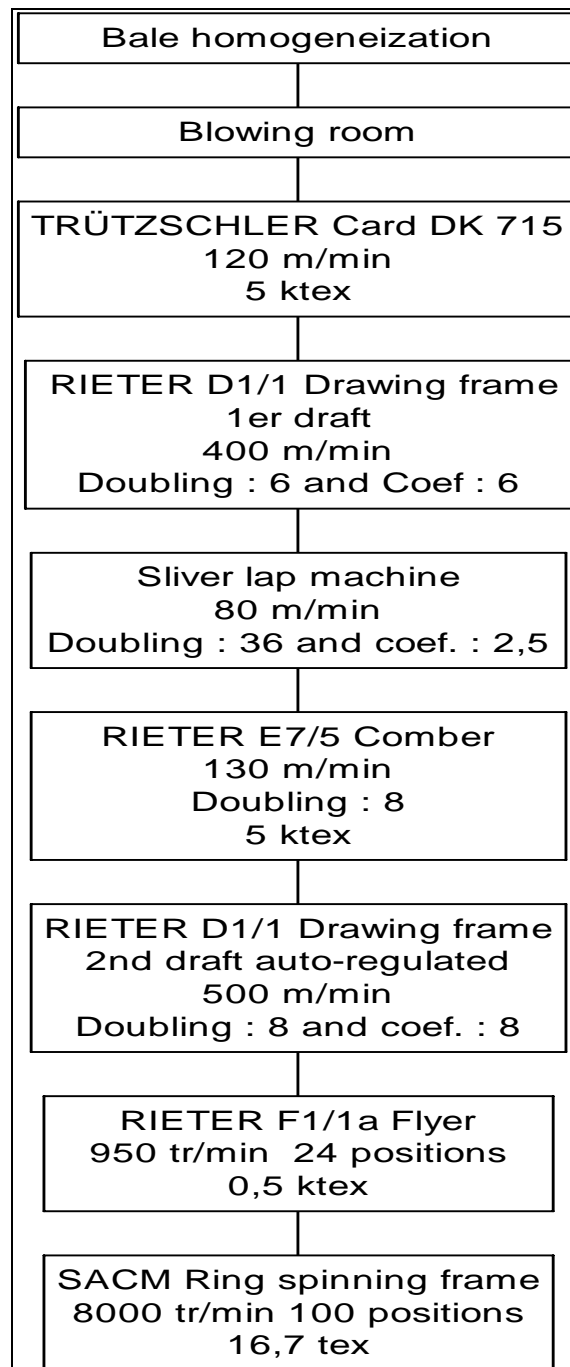


Figure C-61: Operational steps in the combed spinning tests.

C.3.2.2. Hygrometric conditions

These experiments were performed in 3 separate workshops. Preparation to carding operations were conducted at ITF (same conditions as for the carded process tests), then combing was performed in ‘Caulliez frères’ mills (hygroscopic conditions were kept identical to those used in the mill), and spinning was performed at ITF. To summarize:

Preparation and carding: 45 to 50% relative humidity and 23 to 27 °C

Combing: 40 to 45% relative humidity and 26 to 30 °C

Spinning: 55 to 60% relative humidity and 23 to 27 °C.

These conditions were checked every hour to ensure that no drift occurred with respect to the settings.

C.3.2.3. Sampling, problem records and planned analysis

The same procedures as in the carded process tests were used for the preparation and carding operations. During the combing operation, samples were taken from the fleeces at the sliver lap machine level and from slivers and combing noils at the combing machine. The same procedure as for the carded process tests was followed for spinning.

Ten samples were taken at regular intervals to check for changes in production parameters.

All breaks, incidents, cleanings were recorded in the same manner as for the carded process experiments for the corresponding machines, and new recording forms were designed to record events at the combing operation taking care of the specificities of these equipments.

The time required for each operation and the quantity of processed materials used were recorded to evaluate breakages and efficiencies.

All the samples collected were analyzed in the same way as for the carded process experiment, to which were added tests on samples collected at the combing level using SCT and H2SD measurements to trace stickiness in their products.

C.3.3. Results and discussion

C.3.3.1. Changes in stickiness in the course of the process

Results from samples collected at each step in the process were used to monitor stickiness throughout the process, from the bale to the comber sliver.

In the same manner, as for the carded process experiments, the number of sticky points remained constant from the bale to the combing machine sliver (Table C-20). At this point, the number of sticky points decreased because the comb removes some sticky points that are then transferred to the combing noils.

Table C-20: Changes in stickiness in the course of the process (mean of 10 H2SD replicates).

Bale	Raw Cotton	Laroche Cotton	RN Cotton	RSK Cotton	Card sliver	Roll Comber	Combing noils	Comber sliver
BR03	17	15	14	7	7	10	35	4
BR07	10	8	11	11	8	4	11	2
BR12	8	10	11	9	5	4	11	3
BR14	6	5	3	3	2	3	21	1
BR16	16	13	12	10	7	7	22	5

C.3.3.2. At the card level

Table C-21 gives the number of breaks, machine stoppages and mass variation of the card slivers in comparison with the stickiness determination (measurement on RSK samples). The number of breaks was calculated for 100 km of sliver. This corresponded to a breakage per hour ratio for a carding room with 14 cards working in our test conditions. The breaks were categorized into three classes: breaks of the web, breaks in the funnel, and those at the can coiler level.

Table C-21: Breaks, efficiency and mass variation of the card sliver.

Bale	H2SD	SCT	Web breaks per 100 km of sliver	Funnel breaks per 100 km of sliver	Can coiler breaks per 100 km of sliver	Total number of breaks per 100 km of sliver	Efficiency%	CV% mass Sliver
BR03	7	6	0	8.5	0	9	78	5.8
BR07	11	8	3.1	0	3.1	6	77	5.7
BR12	9	5	0	3.3	0	3	80	5.1
BR14	3	2	0	10.4	0	10	98	6.2
BR16	10	9	0	9.6	0	10	77	5.7

A moderate effect occurs during the carding of the Barakat bales at the card level. These results are comparable to those obtained in the carded process for bales with a comparable level of stickiness. This could be different with more sticky bales.

C.3.3.3. First draft, drawing frame

A distribution of breakage origins was determined during the tests. Results are expressed in breaks per 100 km of sliver, corresponding to the breakage per hour for 2 drawing frames producing around 450 kg/h (Table C-22).

Breakages were at the same level as Acala cottons processed in the carded process, i.e. bales with a similar level of stickiness. On the other hand, efficiencies are substantially lower than those noted in the carded process. This is due to the large number of machine stoppages required during feeding. Indeed, a doubling of 36 at the sliver lap machine requires a large number of cans compared to the one required in the carded process. Thus the efficiency ratios are more affected by these feeding times than by stickiness.

Table C-22: Breaks, efficiency mass variation of the 1st draft drawing frame.

Bale	H2SD	SCT	Creel breaks Per 100 km of sliver	Funnel breaks per 100 km of sliver	Total breaks per 100 km of sliver	Number of rolling-up per 100 km of sliver	Number of cleanings per 100 km of sliver	Efficiency%	CV% Mass
BR03	7	6	0	0	8	8	0	26	5.47
BR07	11	8	0	0	3	3	0	57	4.79
BR12	9	5	0	6	16	10	0	57	4.04
BR14	3	2	0	0	14	14	14	36	4.51
BR16	10	9	0	0	25	25	0	32	4.15

Sliver mass variations were at the same level as in the carded process.

C.3.3.4. Sliver lap machine

This is a typical machine used in the combed process whose role is to transform drawing frame slivers into a wide enough fleece to be combed. During this operation, a low drafting

ratio is applied to the slivers that are grouped in a large number (high doubling ratio).

We expressed the results (classified depending on their origins) as breakages per 15 km of fleece (Table C-23) corresponding to a machine with 3 positions operating under the same conditions as our tests (80 m/min).

Table C-23: Breaks, efficiency on the sliver lap machine.

Bale	H2SD	SCT	Creel breaks per 15 km of fleece	Drafting zone breaks per 15 km of fleece	Merging zone breaks per 15 km of fleece	Total breaks per 15 km of fleece	Efficiency%
BR03	7	6	0	17.3	0	17.3	47
BR07	11	8	0	13.1	0	13.1	26
BR12	9	5	0	26.9	13.4	40.3	54
BR14	3	2	0	0.0	0	0	80
BR16	10	9	0	19.5	0	19.5	37

This table shows an high number of breaks and relatively low efficiencies. Indeed, except for bale BR14 which showed a low stickiness level, all the bales gave a high number of breaks at the drafting zone level, most often accompanied by rolling up on the cylinders. This explains the relative efficiency decreases compared to bale BR14 (80%).

This operation seems to be very sensitive to stickiness which decreases machine efficiency, even if the stickiness level of the fiber is low.

C.3.3.5. Combing machine

This operation removes the shortest fibers from the cotton fleeces using a rotary comb. The corresponding slivers (one per combing position) are then grouped together to be drawn and condensed into sliver that is packaged in cans.

Results (Table C-24), classified depending on their origins are expressed as the number of breaks per 100 km of sliver. This corresponds to the breakage ratio per hour for 12 combing machines with 8 positions each operating under our conditions (130 m/min; around 40 kg/h).

Table C-24: breaks and efficiency at the combing machine level.

Bale	H2SD	SCT	Feeder breaks per 100 km of sliver	Breaks at the comb per 100 km of sliver	Drafting zone breaks per 100 km of sliver	Total breaks per 100 km of sliver	Efficiency%
BR03	7	6	22	37	15	74	35
BR07	11	8	0	43	6	49	44
BR12	9	5	0	24	18	42	73
BR14	3	2	7	7	0	13	73
BR16	10	9	44	0	0	44	40

The number of breaks is higher at the comb level than elsewhere. The fibers are almost treated one by one at this step in the operation. This implies maximum contact between the fibers and the metallic parts of the machine (mainly the combs) This induces low efficiency numbers for the most difficult bales. Indeed, bale BR14 with a low level of stickiness was processed with little difficulty with a 73% efficiency while the other bales were processed with a high number of breaks (efficiency around 40%).

C.3.3.6. Drawing frame: 2nd draft

Results in Table C-25 are expressed as the number of breaks per 100 km of sliver which corresponds to the production of 2 drawing frames producing 450 kg/hour.

Table C-25: breaks and efficiency at the 2° draft.

Bale	H2SD	SCT	Creel breaks per 100 km of sliver	Funnel breaks per 100 km of sliver	Total breaks per 100 km of sliver	Number of rolling up per 100 km of sliver	Number of cleaning per 100 km of sliver	Efficiency%	CV% mass
BR03	7	6	102	0	102	0	0	39.2	
BR07	11	8	0	0	19	19	0	44.6	3.76
BR12	9	5	0	0	26	26	0	22.4	4.04
BR14	3	2	7	7	14	0	0	39.8	4.69
BR16	10	9	0	0	21	21	0	41.4	

Except for bale BR03, which showed a large number of breaks at the creel level unrelated to stickiness, breakages were at the same level as in the carded process for the same level of stickiness. As far as the efficiency was concerned, all the results were at the same level for all bales and did not show stickiness to have any effect, since efficiencies were established over a short production period (around 1 hour per bale) insufficient for a precise evaluation of this parameter. These numbers were comparable to those observed in the carded process.

C.3.3.7. At the flyer level

Results (Table C-26) are expressed as breaks per 100 km of flyer yarn, corresponding to a machine with 100 positions working under the same conditions

Table C-26: breaks and efficiency at the flyer level.

Bale	H2SD	SCT	Diverse breaks per 100 km of flyer yarn	Breaks induced by stickiness per 100 km of flyer yarn	Flyer breaks per 100 km of flyer yarn	Total breaks per 100 km of flyer yarn	Efficiency%	CV% Mass
BR03	7	6	0	0.94	0.40	1.34	74.7	4.60
BR07	11	8	0.03	1.44	0.00	1.46	76.2	4.76
BR12	9	5	0	0.26	0.60	0.86	84.1	4.79
BR14	3	2	0.05	0.32	0.32	0.69	54.02	4.12
BR16	10	9	0	1.74	0.08	1.82	66.5	4.73

The flyer seems to be unaffected by stickiness. Indeed, the number of breaks and the efficiencies were comparable to those obtained in the carded spinning of non-sticky cottons.

C.3.3.8. Ring spinning frame

Results (Table C-27) are expressed as number of breaks per 1000 positions/hour. Tests for fiber quality, evenness and resistance were performed on 10% of the produced bobbins in this experiment to evaluate the average quality of these yarns.

Table C-27: breaks, imperfections, and efficiency at the ring spinning frame level.

Bale	H2SD	SCT	Breakage 1000 b h	CV% Mass	Thin -50%	Thick +50%	Neps +200%	Hairiness UT3	Elong %	Strength CN/tex	Work to Break N.cm
BR03	7	6	68	14.8	5	288	612	5.41	5.63	18.84	4.2355
BR07	11	8	32	13.7	2	123	239	5.34	5.73	18.68	4.3188
BR12	9	5	31	13.9	3	127	255	5.21	5.51	18.69	4.1284
BR14	3	2	33	15.3	9	308	619	5.81	5.52	17.78	3.9686
BR16	10	9	49	14.3	4	202	416	5.43	5.83	19.25	4.5371

Breakages were at the same level as for the carded process at equivalent stickiness levels. These levels are acceptable and often met in spinning mills.

Tests for fiber quality, evenness CV, the number of imperfections and resistance data corresponded to those published in the Uster statistics for 50 to 95% of spinners worldwide (USTER® 1997).

Since the stickiness range here was rather restricted, the true measure of the effects of stickiness were not fully expressed during these spinning operations.

C.3.4. Conclusion for the combing process

Low levels of stickiness do not substantially disrupt the machines used in the carded process (card, drawing frame, flyer and ring spinning frame) but are difficult to transform at the sliver lap machine and the combing machine, these machine being used in somewhat low relative humidity conditions.

The range of stickiness for the bales we studied is not wide enough to precisely define relations between stickiness and the quality and productivity parameters in the combed process. However, a few points of stickiness will make the difference in the combing operations.

Some information already were described in paragraph C.1.3.4 concerning the effect of the size of the sticky points.

The following paper give the details about the research on the mixing effect on the stickiness level of the cottons.

C.4. Properties of H2SD measurements: proportionality between percentage of sticky cotton and H2SD results, drift over time and independence of successive measurements

C.4.1. Objective

The number of sticky points as measured by H2SD is a density measurement of the sticky points within the sample. The thermodetection principle requires and assumes sufficient cleaning of the card clothing between each sample and the next, without which a contamination effect may be suspected: remaining sticky fibers would contaminate the next sample and increase its count: measurements are no longer independent.

Furthermore, some sticky points next to others may be grouped by the image analysis software and appear as only one sticky point. This problem has a greater chance of appearing when the density of sticky points increases, and a saturation effect may occur with heavily contaminated cottons. It was considered important to check whether this saturation was of practical importance. If it is negligible, the number of sticky points as counted by H2SD is proportional to their density in the sample.

Thus a mix in proportions a and b ($a + b = 1$) of cottons with stickiness potentials X and Y (H2SD readings) should give a cotton mix with a stickiness potential of $aX + bY$: the measurement is linear.

Then, as thermodetection is based on a combination of heat and humidity, it is important to determine the stability of the measurement over time under normal conditions in a fiber laboratory. We attempted to check these three properties: independence, absence of drift and linearity on a complete set of samples with a wide range of stickiness levels.

C.4.2. Materials and methods

A specific experiment was designed to study the mixing of non sticky to sticky cottons. This experiment was carried out with 13 samples of 1 kg of Sudanese cottons, with various stickiness levels (not representative of the extend of stickiness within Sudan), and 2 cottons assumed to be non-sticky (in fact they were very slightly sticky). Each cotton was mixed with a cotton assumed to be non-sticky, in 4 proportions: 25, 50, 75 and 100%. The mixing operation was done on the Cirad laboratory opener. The experiment was performed in 10 repetitions. As this experiment lasted several days, we checked for any drift in the measurements using randomized blocs. To test this drift, we inserted 2 sticky reference cottons every 15 samples. Then, to check the contamination effect, we added a non-sticky cotton after every sticky cotton.

C.4.3. Results and discussion

Results were analyzed using a generalized linear model to take account of a relation between their mean and their variance.

C.4.3.1. Relationship between mean and variance

This was evaluated based on the complete set of samples, without taking account of the block effect. The whole dataset is given in Annex C-1. The results show a linear relationship between the means and variances of H2SD counts, with the slope estimated to be 1.07, which is not significantly different from 1. The offset is significantly greater than 0 ($P=0,015$). Thus, the variance was proportional to the mean. In other words, for each cotton, the distribution of the number of sticky points shows a constant over-dispersion compared to the Poisson distribution. In consequence, we used analysis of variance after square root transformation of

the data or a generalized linear model which takes account of an over-dispersion.

C.4.3.2. Test for drift over time

Results for measurements in reference cottons seem to decrease over time (Figure C-62). The existence of this drift was confirmed by the Phillips-Perron test on each of the reference cottons (Annex C-2), while the auto-correlation of the results is just significant for “333” cotton. During this experiment, which lasted 3 days, we can consider that a slight drift occurred. For data analysis, this drift is compensated by taking account of the block effect, and any auto-correlation is canceled by randomization.

C.4.3.3. Test on the contamination effect

Reference cottons were tested just after a pure sticky cotton or another non-sticky reference cotton. Possible contamination was tested by comparing the measurement means obtained after the different previous samples. To do this, an analysis of variance was performed on the reference cotton results after square root transformation, with one single factor: the cotton prior to the measurement (Annex C-3). The effect of the prior sample was not significant on result for the next sample ($P=0,65$ and $P=0,44$).

Thus, this data showed that the cleaning of the H2SD card is sufficiently effective to guarantee that the analysis of a highly sticky cotton will not affect the results of a subsequent cotton.

C.4.3.4. Proportionality between the proportion of sticky cotton and stickiness measured by H2SD

This was measured on a chart and tested using a generalized linear model.

Consider the set of k cottons with unknown stickiness potential b_1, b_2, \dots, b_k mixed in proportions p_1, p_2, \dots, p_k . If proportionality exists between the sticky points of the sample and stickiness level Y as measured by H2SD, then its expectation should be written:

$$E(Y) = \sum_{i=1}^k b_i p_i$$

(Equation C-19)

If proportionality is not confirmed, the expectation of Y is some function of the considered mix:

$$E(Y) = f(b_i, p_i)$$

(Equation C-20)

We have seen that the variance of Y is proportional to its expectation. Y then follows in both cases a generalized linear model with over-dispersion, which is suitable for the simple test of the non-proportionality per likelihood comparison of the models (Equation C-19) and (Equation C-20).

An apparent proportionality between the proportion of sticky cotton and stickiness measurement results by H2SD appears, except for the 3 most sticky cottons where the “100% in the mix” point is not aligned with the other points: the 100% proportion shows less sticky points than would be expected by measurements made on the mix (Figure C-63)

The test of the likelihood ratio confirms this impression: in the set of cottons, the non-proportionality test is significant (Table C-28a): the measurement is not linear. By contrast, when the 3 most sticky cottons are eliminated, the test becomes non-significant: the measurement becomes linear (Table C-28b). We can conclude that the measurement is linear under 40 sticky points, but not up to 60.

Table C-28: Non-proportionality test between the measurement of stickiness by H2SD and the proportion of sticky cotton.

Table 26a: all cottons taken in account

	Deviance	Df	Deviance/df	P>F
Model with proportional count (1)	1677.5829	729		
Model with any count (2)	1526.6226	690	2.43127957	
Difference	150.9603	39	3.87077692	
Test F			1.59207398	<0.05

Table 26b: the 3 most sticky cottons are eliminated

	Deviance	Df	Deviance/df	
Model with proportional count (1)	1335.4396	612		
Model with any count (2)	1273.3129	582	2.29456976	
Difference	62.1267	30	2.07089	
Test F			0.90251778	N.S.

C.4.4. Conclusion

The over-dispersion observed in this experiment seems to be in contradiction with the binomial negative distribution observed with H2SD (Tamime et al, 1999). Indeed, for the binomial negative law, the over-dispersion is not constant, but increases with the mean. However, the negative binomial distribution is observed between the different layers of a bale (227kg), whereas the less dispersed distribution is observed within a fiber sample of 1 kg, thoroughly mixed by the Cirad laboratory opener.

The existence of a slight drift induces a need for a periodical check or calibration of the H2SD using reference cottons of known stickiness. The quality of the mix for these reference cottons is essential to obtain homogeneous reference cottons.

The measurement is not subject to saturation up to 40 sticky points. If the goal is to classify stickiness in 2 classes (sticky or not), the threshold would be anyway far lower than 40 sticky points, and there is no need to envisage corrections.

By contrast, if the stickiness potential of highly contaminated cottons needs to be evaluated, an extra experiment would be necessary with a range of highly sticky cottons, to specify the observed non-linearity.

To sum up, the stickiness of a binary mix can be tabulated as a function of H2SD data on individual cottons and their percentage in the mix. It would be necessary to check the effect of stickiness from that binary mix onto the spinning process and yarn quality, and match the conclusion to that obtained in the industrial spinning experiment. In conclusion, these results confirm that mixing cottons with different stickiness potentials is an appropriate solution to decrease the stickiness level of the mix, and this should reduce disruption during spinning.

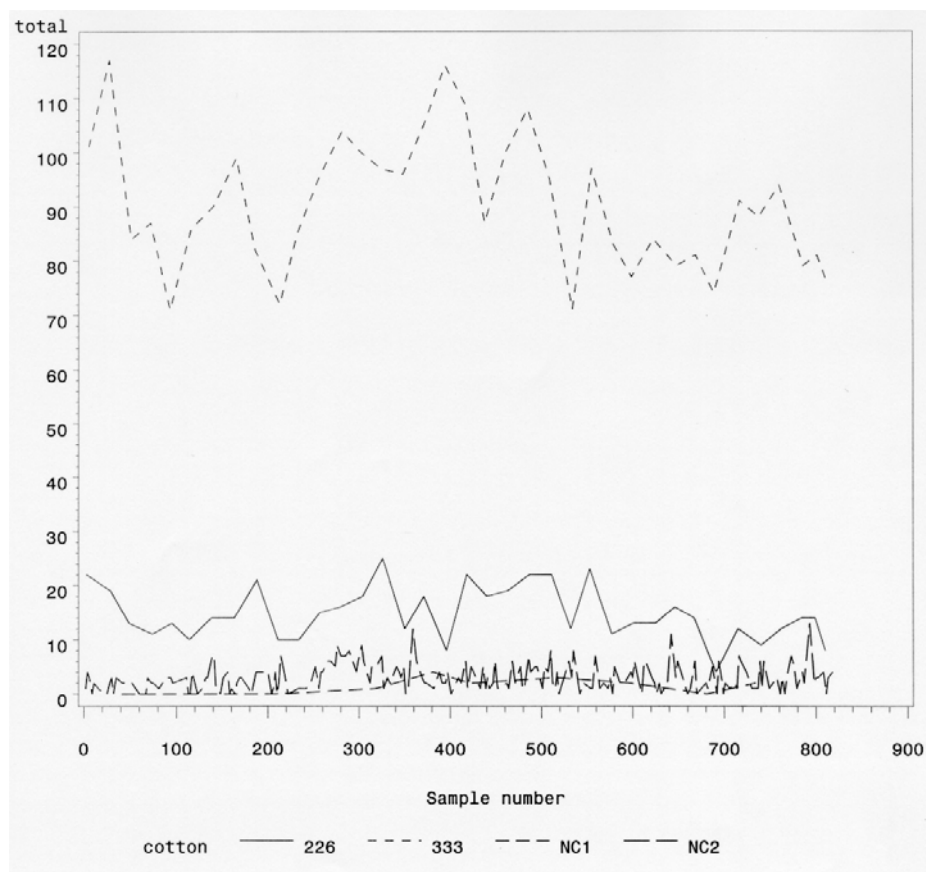


Figure C-62: Plot of control cottons: H2SD results vs time.

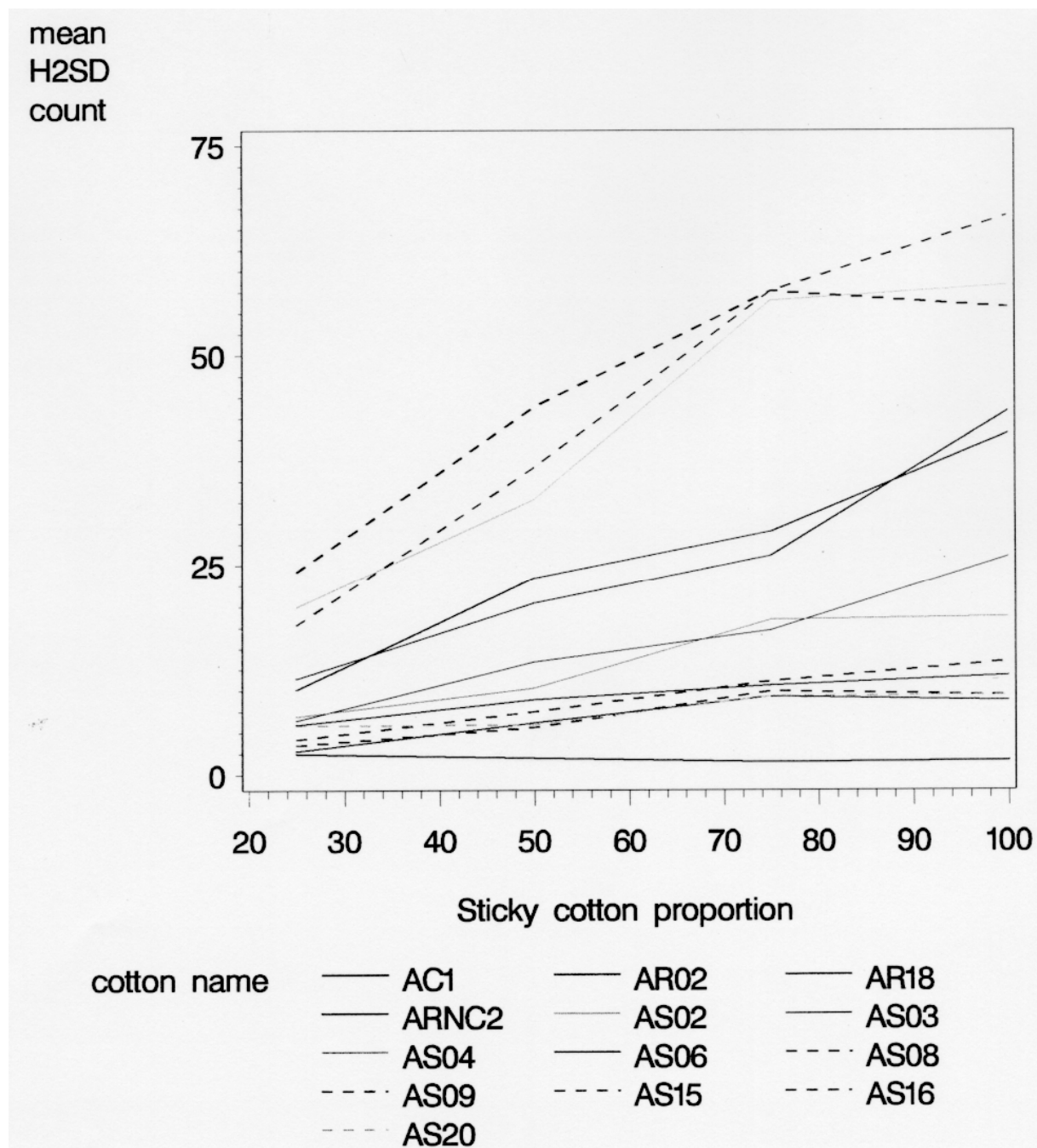
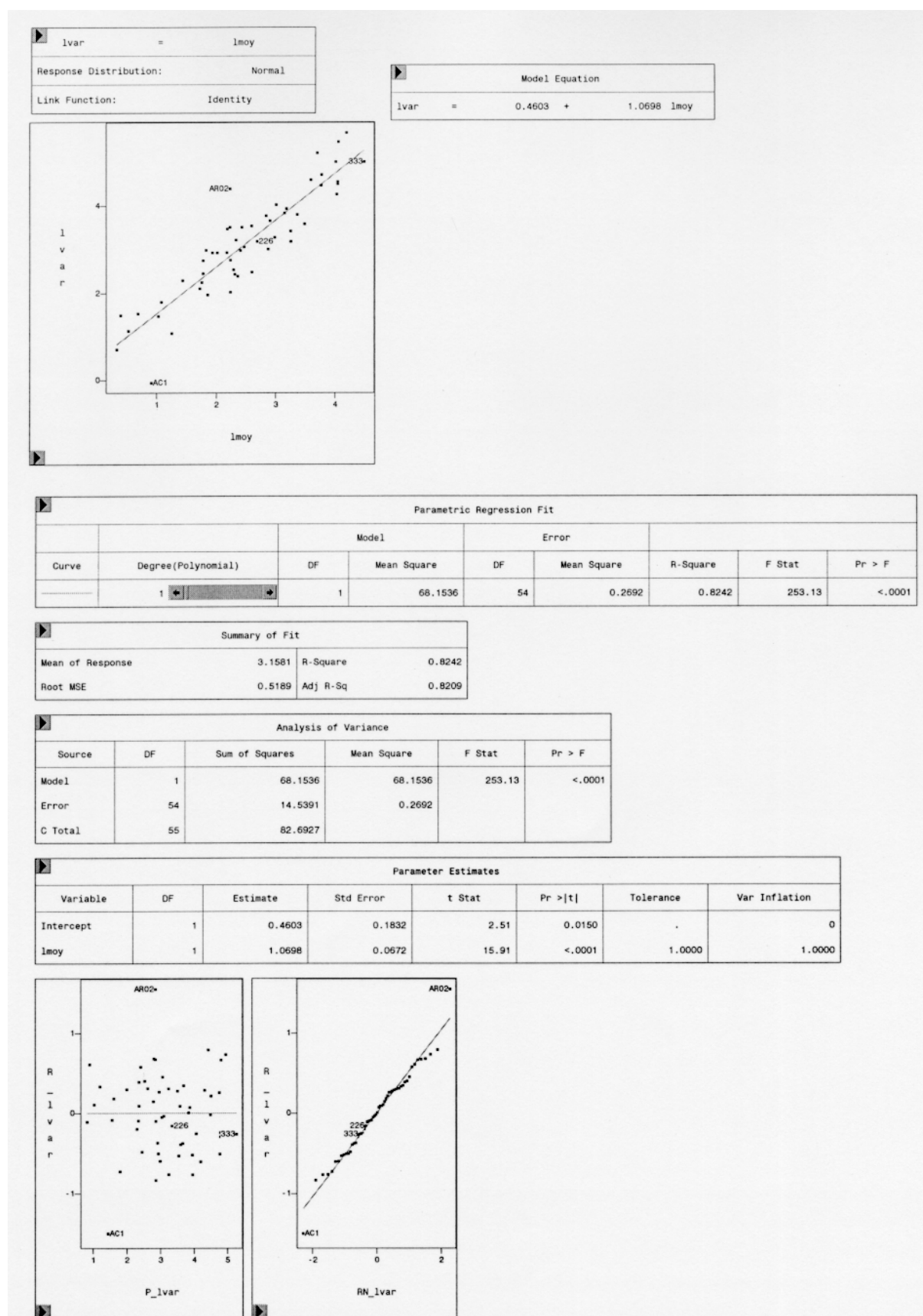


Figure C-63: Linear relation between the proportion of sticky cotton and H2SD results: measured stickiness is questionable when stickiness exceeds 50 sticky points.

Annex C-1: Relationship between mean and variance.



Annex C-2: Test on the drift vs time for cotton "333".

Figure C-2

The ARIMA Procedure

Name of Variable = sqrtot

Mean of Working Series 9.482643
Standard Deviation 0.635456
Number of Observations 37

Autocorrelations

Lag	Covariance	Correlation	-1	9	8	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	8	9	1	Std Error
0	0.403805	1.00000												*****										0
1	0.165099	0.40886												*****										0.164399
2	0.064285	0.15920												***										0.189902
3	0.021721	0.05379												*										0.193476
4	0.098701	0.24443												*****										0.193880
5	0.073552	0.18215												****										0.202036
6	0.054092	0.13396												***										0.206427
7	-0.012016	-0.02976												*										0.208763
8	-0.121693	-0.30137												*****										0.208878
9	-0.098255	-0.24332												*****										0.220316

"," marks two standard errors

Inverse Autocorrelations

Lag	Correlation	-1	9	8	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	8	9	1
1	-0.30388										*****											
2	-0.03253										*											
3	0.18969											****										
4	-0.37312										*****											
5	0.07711											**										
6	-0.03197										*											
7	-0.14590										***											
8	0.26140											*****										
9	0.01828																					

Partial Autocorrelations

Lag	Correlation	-1	9	8	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	8	9	1
1	0.40886										*****											
2	-0.00956																					
3	-0.00962																					
4	0.27267										*****											
5	-0.01451																					
6	0.03524										*											
7	-0.10273										**											

The ARIMA Procedure

Partial Autocorrelations

Lag	Correlation	-1	9	8	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	8	9	1
8	-0.39924								*****													
9	-0.02653									*												

Autocorrelation Check for White Noise

To Lag	Chi- Square	DF	Pr > ChiSq	-----Autocorrelations-----						
6	12.81	6	0.0461	0.409	0.159	0.054	0.244	0.182	0.134	

Phillips-Perron Unit Root Tests

Type	Lags	Rho	Pr < Rho	Tau	Pr < Tau
Zero Mean	0	-0.2301	0.6253	-0.53	0.4789
	1	-0.2006	0.6319	-0.56	0.4664
	2	-0.1862	0.6352	-0.59	0.4527
	3	-0.1684	0.6392	-0.68	0.4173
	4	-0.1669	0.6396	-0.69	0.4122
	5	-0.1649	0.6400	-0.70	0.4050
	6	-0.1648	0.6400	-0.70	0.4048
	7	-0.1670	0.6395	-0.69	0.4127
	8	-0.1633	0.6404	-0.72	0.3983
Single Mean	9	-0.1602	0.6411	-0.75	0.3830
	0	-20.6337	0.0037	-3.65	0.0090
	1	-19.8254	0.0049	-3.60	0.0102
	2	-19.9161	0.0048	-3.61	0.0101
	3	-19.0946	0.0063	-3.56	0.0115
	4	-20.2668	0.0042	-3.63	0.0096
	5	-21.3537	0.0028	-3.70	0.0080
	6	-22.5635	0.0018	-3.77	0.0066
	7	-23.6313	0.0012	-3.84	0.0056
Trend	8	-23.5921	0.0012	-3.83	0.0056
	9	-23.3563	0.0014	-3.82	0.0058
	0	-22.1083	0.0174	-3.80	0.0283
	1	-21.7414	0.0195	-3.78	0.0297
	2	-21.9447	0.0183	-3.79	0.0289
	3	-21.1666	0.0232	-3.74	0.0319
	4	-22.2837	0.0165	-3.81	0.0277
	5	-23.2678	0.0121	-3.86	0.0243
	6	-24.2878	0.0087	-3.92	0.0212
	7	-25.1083	0.0066	-3.97	0.0190
	8	-24.7169	0.0075	-3.95	0.0200
	9	-24.0379	0.0094	-3.91	0.0219

The ARIMA Procedure

Name of Variable = sqrtot

Mean of Working Series 3.7898
Standard Deviation 0.648998
Number of Observations 37

Autocorrelations

Lag	Covariance	Correlation	-1	9	8	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	8	9	1	Std Error
0	0.421198	1.00000												*****										0
1	0.042333	0.10051									.			**		.								0.164399
2	0.096060	0.22806									.			*****		.								0.166051
3	-0.0050231	-.01193									.					.								0.174312
4	0.024636	0.05849									.			*		.								0.174334
5	0.0086022	0.02042									.					.								0.174863
6	0.089726	0.21303									.			****		.								0.174928
7	0.027818	0.06604									.			*		.								0.181804
8	0.017098	0.04059									.			*		.								0.182451
9	-0.148028	-.35145									*****					.								0.182695

"," marks two standard errors

Inverse Autocorrelations

Lag	Correlation	-1	9	8	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	8	9	1
1	-0.00220									.				.								
2	-0.24579									*****				.								
3	-0.09086									.	**			.								
4	0.07035									.	*			.								
5	0.04929									.	*			.								
6	-0.16574									.	***			.								
7	-0.17420									.	***			.								
8	0.00715									.				.								
9	0.31189									.			*****	.								

Partial Autocorrelations

Lag	Correlation	-1	9	8	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	8	9	1
1	0.10051									.			**	.								
2	0.22019									.			****	.								
3	-0.05513									.	*			.								
4	0.01481									.				.								
5	0.03101									.			*	.								
6	0.20420									.			****	.								
7	0.02527									.			*	.								

Annex C-3 (continued): Test on drift vs time on cotton "226".

The ARIMA Procedure

Partial Autocorrelations

Lag	Correlation	-1	9	8	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	8	9	1
8	-0.06367									.	*				.							
9	-0.39919									*****					.							

Autocorrelation Check for White Noise

To Lag	Chi-Square	DF	Pr > ChiSq	-----Autocorrelations-----						
6	4.84	6	0.5650	0.101	0.228	-0.012	0.058	0.020	0.213	

Phillips-Perron Unit Root Tests

Type	Lags	Rho	Pr < Rho	Tau	Pr < Tau
Zero Mean	0	-1.3458	0.4122	-1.02	0.2726
	1	-0.8805	0.4882	-0.98	0.2860
	2	-0.8728	0.4896	-0.98	0.2855
	3	-0.7987	0.5034	-1.00	0.2782
	4	-0.7714	0.5086	-1.01	0.2758
	5	-0.7287	0.5169	-1.03	0.2658
	6	-0.7309	0.5165	-1.03	0.2664
	7	-0.7337	0.5160	-1.03	0.2672
	8	-0.7747	0.5080	-1.01	0.2764
	9	-0.7458	0.5136	-1.02	0.2703
Single Mean	0	-32.0878	0.0002	-5.21	0.0002
	1	-31.0610	0.0002	-5.19	0.0002
	2	-33.7233	0.0002	-5.25	0.0002
	3	-34.8948	0.0002	-5.28	0.0002
	4	-36.1224	0.0002	-5.31	0.0002
	5	-37.1618	0.0002	-5.35	0.0002
	6	-39.0505	0.0002	-5.41	0.0002
	7	-40.7563	0.0002	-5.46	0.0002
	8	-42.2182	0.0002	-5.51	0.0002
	9	-42.2022	0.0002	-5.51	0.0002
Trend	0	-33.2787	0.0003	-5.31	0.0006
	1	-32.6768	0.0004	-5.30	0.0006
	2	-35.3702	0.0001	-5.35	0.0005
	3	-36.4109	<.0001	-5.38	0.0005
	4	-37.3892	<.0001	-5.41	0.0005
	5	-38.1618	<.0001	-5.43	0.0004
	6	-39.7857	<.0001	-5.48	0.0004
	7	-41.3149	<.0001	-5.53	0.0003
	8	-42.6406	<.0001	-5.57	0.0003
	9	-42.4670	<.0001	-5.57	0.0003

Annex C-4: Test of the effect of preceding cotton.

Test of the effect of preceeding cotton on H2SD measurement of non-sticky control NC1 103
14:33 Friday, January 19, 2001

The FREQ Procedure

precedant	Frequency	Percent	Cumulative Frequency	Cumulative Percent
AR18	2	20.00	2	20.00
ARNC2	1	10.00	3	30.00
AS03	1	10.00	4	40.00
AS15	2	20.00	6	60.00
AS16	1	10.00	7	70.00
NC2	3	30.00	10	100.00

The GLM Procedure

Class Level Information

Class	Levels	Values
precedant	6	AR18 ARNC2 AS03 AS15 AS16 NC2

Number of observations 10

Dependent Variable: sqrt_total

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	2.77391838	0.55478368	0.70	0.6530
Error	4	3.17157288	0.79289322		
Corrected Total	9	5.94549126			

R-Square	Coeff Var	Root MSE	sqrt_total Mean
0.466558	99.21740	0.890446	0.897469

Source	DF	Type I SS	Mean Square	F Value	Pr > F
precedant	5	2.77391838	0.55478368	0.70	0.6530

Source	DF	Type III SS	Mean Square	F Value	Pr > F
precedant	5	2.77391838	0.55478368	0.70	0.6530

The GLM Procedure Least Squares Means

precedant	sqrt_total LSMEAN	Standard Error	Pr > t
AR18	1.70710678	0.62964006	0.0535
ARNC2	1.41421356	0.89044552	0.1874
AS03	-0.00000000	0.89044552	1.0000
AS15	0.70710678	0.62964006	0.3243
AS16	1.00000000	0.89044552	0.3243
NC2	0.57735027	0.51409896	0.3243

Test of the effect of preceeding cotton on H2SD measurement of non-sticky control NC2 107
14:33 Friday, January 19, 2001

The FREQ Procedure

precedant	Frequency	Percent	Cumulative Frequency	Cumulative Percent
226	37	17.29	37	17.29
333	37	17.29	74	34.58
AC1	10	4.67	84	39.25
AR02	10	4.67	94	43.93
AR18	10	4.67	104	48.60
ARNC2	10	4.67	114	53.27
AS02	10	4.67	124	57.94
AS03	10	4.67	134	62.62
AS04	10	4.67	144	67.29
AS06	10	4.67	154	71.96
AS08	10	4.67	164	76.64
AS09	10	4.67	174	81.31
AS15	10	4.67	184	85.98
AS16	10	4.67	194	90.65
AS20	10	4.67	204	95.33
NC1	10	4.67	214	100.00

Test of the effect of preceeding cotton on H2SD measurement of non-sticky control NC2 108
14:33 Friday, January 19, 2001

The GLM Procedure

Class Level Information

Class	Levels	Values
precedant	16	226 333 AC1 AR02 AR18 ARNC2 AS02 AS03 AS04 AS06 AS08 AS09 AS15 AS16 AS20 NC1

Number of observations 214

The GLM Procedure

Dependent Variable: sqrt_total

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	10.6947577	0.7129838	1.02	0.4369
Error	198	138.5205712	0.6995988		
Corrected Total	213	149.2153289			

R-Square	Coeff Var	Root MSE	sqrt_total Mean
0.071673	55.74487	0.836420	1.500443

Source	DF	Type I SS	Mean Square	F Value	Pr > F
precedant	15	10.69475768	0.71298385	1.02	0.4369
Source	DF	Type III SS	Mean Square	F Value	Pr > F
precedant	15	10.69475768	0.71298385	1.02	0.4369

The GLM Procedure
Least Squares Means

precedant	sqrt_total LSMEAN	Standard Error	Pr > t
226	1.40981917	0.13750664	<.0001
333	1.80967825	0.13750664	<.0001
AC1	1.24020972	0.26449931	<.0001
AR02	1.60326139	0.26449931	<.0001
AR18	1.71389627	0.26449931	<.0001
ARNC2	1.36955254	0.26449931	<.0001
AS02	1.39735562	0.26449931	<.0001
AS03	1.54468274	0.26449931	<.0001
AS04	1.41496593	0.26449931	<.0001
AS06	1.53313090	0.26449931	<.0001
AS08	1.47102464	0.26449931	<.0001
AS09	1.14740693	0.26449931	<.0001
AS15	1.92482182	0.26449931	<.0001
AS16	1.28882829	0.26449931	<.0001
AS20	1.08637033	0.26449931	<.0001
NC1	1.46184003	0.26449931	<.0001

C.5. Effects of relative humidity on the spinning process and yarn quality

C.5.1. Objective

It is possible, through measurement of the stickiness of raw cotton, to predict the disruption that may occur during spinning. Now, this experiment is designed to answer the question: what is the effect of relative humidity on the spinning process and the quality of the yarn ?

C.5.2. Materials and methods

Seven cottons were selected from the 24 cottons spun at ITF during the industrial spinning study to cover a range of stickiness. These cottons were obtained from the Laroche mix. One spinning test was performed for each cotton with two types of spinning – open-end or rotor spinning (OE) and ring spinning (RS) in three relative humidity conditions (40, 45, 55%).

For industrial carded varieties of cotton, the procedure is as follows: first opening and blending of cotton, then carding, condensation of the web in a sliver, drawing steps, flyer and spinning. As far as the micro-spinning is concerned, the previous procedure was adapted in line with the quantity of the cotton fibers to be spun (Frydrych and Dréan, 2000).

The micro-spinning stages for an amount of cotton ranging from 50 to 500g are shown in Figure C-64.

Cirad uses Platt micro-spinning equipment which consists of a mini-card, a drawing frame and an eight-spindles spinning frame with double drawing, as well as six Suessen open-end rotors.

C.5.2.1. General micro-spinning steps

The full set of spinning tests were to be conducted in three steps (Figure C-64).

C.5.2.1.1. First step: opening and carding

Fiber preparation consisted of blending, cleaning, disentangling fibers. It could be split into the two following stages:

- cotton opening and blending on the Cirad cotton opener for samples of 50 g and over; samples of 250 g to 500 g were split into 5 parts of 50 or 100g.
- carding operation provided the cleaning, disentangling and paralleling of fibers while eliminating a part of the neps and short fibers. Depending on the starting weight of the sample, i.e. 50 or 100 g, the outgoing web of a weight of 5g/m² was taken by the cylinder, with respective lengths 0.77 m or 1.57 m. In our case, the 5 sub-samples were carded into 5 fleeces.

C.5.2.1.2. Second step: drawing

The drawing consisted in passing the fibrous flow (fleece or sliver) between four pairs of pressing cylinders, driven at different tangential speeds. In all cases, it was necessary to perform three drawing operations. The first passage changed the card outgoing fleece into a sliver. The two other operations correspond to those performed in an industrial plant. Two methods:

- sliver from the sample of 50 g is collected on a drum;
- sliver from the sample of 250 g and over is collected in cans.

In our case, we ran our 5 fleeces of 100 g on the first pass of the drawing frame to produce 5 slivers. These 5 slivers altogether (for a doubling) fed the second passage on the drawing frame to produce 10 slivers. For the third passage, the 10 slivers altogether (for a doubling) fed the drawing frame to produce 4 cans (one can per spinning position for both OE and RS spinning).

C.5.2.1.3. Third step: ring spinning and rotor spinning

Spinning consists of winding the yarn on a support. The two main types were being used: ring spinning (RS) and rotor spinning (OE).

The micro-spinning methodology for the relative humidity study is described in

Figure C-65.

For this study we used methodology based on 500 g of cotton per test, with the two types of spinning (OE and RS). This methodology was duplicated for each of the three ambient conditions: 40%RH and 27 °C, 45%RH and 22 °C; 55%RH and 27 °C.

During industrial spinning at ITF, eight kilograms of fibers per cotton were taken from the Laroche opening machine for the seven selected cottons. One kilogram from each was sampled for each relative humidity condition, 40%, 45%, 55% per type of spinning.

For each humidity condition and for each cotton, 10 samples of 100 g were worked out per spinning. Different yarn counts were performed depending on the spinning process: 20 tex for the ring spinning process, and 27 tex for the open-end process.

The randomization designated work at 45% humidity first, then at 55%, and finally at 40% RH. The order in which the seven cottons were spun in each humidity experiment was randomly organized.

The organization of this experiment is illustrated in

Figure C-65 and discussed below.

C.5.2.1.4. Opener

Twenty samples of each cotton (100 g x 10 for RS, 100 g x 10 for OE) were prepared one after the other. No notes were taken since this was simply an opening / blending operation of the raw material.

C.5.2.1.5. Mini-card

Stickiness level was evaluated during the carding on the small cylinder (perimeter = 0.77m). The evaluation was made fleece after fleece, and also taking care to the time. Four grades of stickiness were defined:

- grade 1; non sticky, no deposit on the 2 cylinders (upper and lower);
- grade 2; slight stickiness; some deposits, some rising, possible rolling up;
- grade 3; medium stickiness; rising and many deposits, rolling up;
- grade 4; high stickiness; high rising, many deposits, high rolling up, web break.

The evaluation time was up to rolling-up while recording the time required to get them. Then, in case of sticky cottons, after 3 rolling up, the cotton was considered as highly sticky, and the upper cylinder of the card was removed to continue the carding process of the remaining cotton sample.

The outcome products at the card level are 20 fleeces (100 g each, Slide C-35). In order to produce two replicates of RS and OE yarns, this set of 20 fleeces is divided into 2 groups of 10 fleeces, each group being processed by a doubling of 5 fleeces. Thus 4 groups of fleeces were processed on the drawing frame: 5 fleeces for RS, repetition 1; 5 fleeces for RS, repetition 2; 5 fleeces for OE, repetition 1, 5 fleeces for OE, repetition 2 respectively.

C.5.2.1.6. Drawing

For each spinning repetition, 5 fleeces were transformed to form sliver (Slide C-36 to Slide C-38). The drawing roller was cleaned between each 500 g or following accumulation of stickiness which led to breakage of the sliver. All the incidents, interventions concerning the rolling-up were noted. The slivers from each repetition were collected in 4 cans for the ring-spinning and 2 cans for the open-end spinning.

C.5.2.1.7. Ring spinning

The four slivers of stickiness for each repetition were spun on 4 independent spindles (Slide C-39).

Each spindle produced 8 cops (1 cop at each doffing).

Observations made during spinning, and mainly at the back drawing of the spinning concerned:

- spinning disruptions or breakages (induced or not by stickiness);
- presence or absence of sticky points deposited on the back draught roller (in some case, we also noted deposits on the front roller) causing the fiber to wrap around the roller;
- manual interventions or cleanings to prevent spinning from being interrupted.

C.5.2.1.8. Open-end

Two slivers were used per repetition. Each sliver fed one rotor and gave 1 bobbin per repetition. Observations made during spinning concern:

- number of spinning disruptions or yarn breakages (induced or not by stickiness)
- number of rotor cleanings.

C.5.2.2. Yarn quality characterization

C.5.2.2.1. UT3 evenness tester

The following evenness tester machine settings were used:

- RS: speed 100 m/min, thin (-50%), thick (+50%), neps (200%), slot 1 (20 tex)
- OE: speed 100 m/min, thin (-50%), thick (+50%), neps (280%), slot 2 (>21 tex)

The tests were conducted as follows:

- Yarn tests in ring spinning

Every cop produced was UT3 tested (i.e. 64 cops * 250 m/cops = 16000 m tested).

- Yarn in open-end

2 repetitions x 2 bobbins x 1 km x 4 measurements, i.e 16000 m.

- Detailed analysis of RS yarn: a detailed neps analysis was performed using a method

developed at Cirad to identify the different types of neps observed. During this measurement, the evenness tester stops the flow of the yarn at the appropriate position so that every nep is examined in detail through a magnifying lens under intense light and classified as seed coat fragment, fiber neps, (entangled and sticky neps), fragments such as leaves or sticky neps. Percentages obtained for each type of imperfection were adjusted to total neps on 1000 m to obtain the number of neps per type of imperfection on 1000 m. This detailed analysis was performed on 1/8th of the cops produced on 1000 m of yarn (first doffing of 4 cops per repetition) for a total of 2000 m.

- Detailed analysis of OE yarn: the same method as for ring spun yarns was employed to characterize the neps on OE yarn on 4 bobbins with 2 measurements (1000 m each) for a total of 8000 m.

C.5.2.2.2. Tenacity using Tensorapid 3

Yarn strength took account of the yarn count as determined by UT3 measurement.

- Ring spinning

Only 3/8th of the 64 cops were tested on Tensorapid because testing time was long (20 seconds per break, 40 breaks / cop) for a total of 960 breaks. The cops chosen corresponded to the first, fourth and eighth produced at each single spinning position. Thus, 12 cops were tested per repetition.

- Open-end

Two bobbins * 2 repetitions x 40 breaks x 4 measurements = 640 breaks.

C.5.3. Results and discussion

C.5.3.1. Effect on the spinning process

C.5.3.1.1. At the card level

The figures below only show a fitted line if a significant relation was detected between the measured criteria and the stickiness level of the given cottons.

Figure C-66 shows that stickiness had a significant effect on the rolling-up at the card level when RH was 45%, while no trend was noted at 55%RH since it appeared to bring immediate troubles for any cotton stickiness level. None of the cottons caused disruption at 40% RH. A saturation effect was noted in the number of rolling-up at 55%RH because the operating procedure employed did not record any rolling-ups after the third occurrence. Some examples of the effect of stickiness at the card level are given in Slide C-40 to Slide C-43.

It should be noted that these results take account of the accumulation of stickiness phenomena occurring for a complete set of 10 fleeces except when more than 3 rollings-up occurred.

As far as time till onset of rolling-up is concerned, the highest relative humidity levels (45 and 55% RH) were seen to have a significant effect, as illustrated in figure C-67. Any rolling-up at 40% occurred after a very long time (as shown in figure C-66 for the most sticky cotton).

C.5.3.1.2. At the drawing frame level

A significant relation was noted between the number of rollings-up and the stickiness level at 55%RH (Figure C-68). However, the number of interventions (where production did not need

to be halted, Figure C-69) and cleaning (the machine is stopped for this operation, Figure C-70) on the drawing frame increased with stickiness as soon as the relative humidity increased. Some stickiness-induced problems are shown in Slide C-44 and Slide C-45.

C.5.3.1.3. At the OE spinning level

A trend was noted between breakages and stickiness for the highest RH (Figure C-71), while no significant relation was found concerning the cleaning of the machinery (Figure C-72).

It should be noted that cleaning operations were only performed after a breakage, and only if a sticky deposit was observed in the rotor (Slide C-46 and Slide C-47).

C.5.3.1.4. At the Ring Spinning frame level

Figure C-73 shows the number of cleanings required to render the machine productive. These cleanings were performed when yarn production was stopped (the yarn was broken) unless this cleaning was required to maintain yarn production (for instance, when too many breaks were observed in a short time due to stickiness accumulation).

At 40%RH, almost no cleaning was required to maintain production, whatever the stickiness level of the raw cotton. At 45 and 55% RH, cleaning was required to maintain yarn production.

The overall increase in the number of interventions, as a function of RH and stickiness levels during these experiments on all machines we used, probably had an effect on the quality of the yarn. Thus, the cleaning and intervention operations removed some potential irregularities from the yarn. In other words, our interventions were performed to maintain yarn production, but they also indirectly improved the final quality of the yarn. Thus, the yarn quality results in this experiment were not only dependent on stickiness and RH% conditions but also on the number of cleaning/interventions. We will have to take this into consideration when looking at yarn quality results below.

C.5.3.2. Effect on yarn quality

Depending on the type of spinning (RS or OE), different categories of neps were counted on the yarn by the evenness tester as defined in standards: neps 200% for RS yarns, and neps 280% for OE yarns.

C.5.3.2.1. Quality of Ring Spun yarns:

An analysis of variance of the results of this study was performed in a split-plot factorial (1/2*3) design for the main yarn quality characteristics. The results are presented in Table C-29. Data for the counts were assumed to follow a Poisson distribution because their distribution should be even within the yarn because of the mixing process conducted while spinning. Thus, to normalize their variance, these counts were transformed through a square root calculation. However for clearer understanding of the results, the charts use raw and real scale data.

Table C-29: Analysis of variance of the data collected in the RH experiment on RS yarns.

RH SUDAN YARN ANALYSIS, 3 HUMIDITIES, 7 COTTONS, Ring Spinning, 2 SETS

File: RH UT3 Title: RH SUDAN UT3

NUMBER of OBSERVATIONS: 84

DISPOSITIF DE L'ESSAI: SPLIT-PLOT 1/2

FACTEUR 1: 3 HUMIDITES 40% (40%), 45% (45%), 55% (55%)

FACTEUR 2: 7 COTONS 1 (AS02), 2 (AS09), 3 (AC1), 4 (AS04), 5 (AS10), 6 (AS20), 7 (AS05)

FACTEUR 3: 2 BLOCS BLOC 1 (B1), BLOC 2 (B2)

	CVM	RAC. THIN	RAC. THICK	RAC. NEPS 200%	Hairiness Yarn	Elong. Yarn	TEN. Yarn	CV TEN.
Res. Suspects	0	0	0	2	2	0	0	0
F Hum.	0,0056	0,0021	0,0056	0,0306	0,1501	0,0010	0,0111	0,0853
ETR 1	0,19	0,69	0,48	1,33	0,19	0,04	0,16	0,37
CV 1 (%)	0,8	2,5	1,3	4,2	3,1	0,8	1,3	2,8
F Cot.	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
Int. HxC	0,0000	0,0012	0,0000	0,0000	0,0000	0,1042	0,1272	0,0273
ETR 2	0,23	1,19	0,86	1,22	0,06	0,10	0,29	0,78
CV 2 (%)	1,0	4,4	2,3	3,9	0,9	2,0	2,3	5,9
Gen. Mean	23,05	26,95	37,25	31,28	6,11	5,21	12,53	13,21
40%	23,75a	30,74 a	38,99 a	32,43 a	6,23	5,57 a	12,22 b	13,55
45%	22,70b	25,93 b	36,33 b	29,04 b	6,13	5,11 b	12,44 b	12,89
55%	22,72b	24,18 c	36,43 b	32,37 a	5,98	4,97 c	12,94 a	13,19
1 (AS02)	23,76b	29,32 bc	40,49 a	37,97 a	6,13 d	5,34 b	12,43 c	12,82 cd
2 (AS09)	24,13a	32,62 a	40,02 a	29,35 c	6,42 b	4,94 d	11,42 e	14,14 ab
3 (AC1)	20,28d	15,68 e	29,40 d	27,52 d	5,21 f	5,59 a	14,16 a	10,94 e
4 (AS04)	23,64b	29,96 b	38,48 b	29,21 c	6,57 a	4,79 e	11,86 d	14,89 a
5 (AS10)	24,01ab	30,44 b	39,94 a	32,87 b	6,40 b	5,02 d	12,05 d	13,59 bc
6 (AS20)	21,72c	22,50 d	32,17 c	24,98 e	5,81 e	5,61 a	13,21 b	12,34 d
7 (AS05)	23,84ab	28,14 c	40,25 a	37,08 a	6,26 c	5,20 c	12,59 c	13,75 abc

As stated in many publications, yarn quality is dependent upon fiber quality. In this study, stickiness had difference effects on yarn quality depending on the relative humidity in the spinning room. However, since most of the cottons used in the study were of similar quality, most of the effects observed were considered to be due to stickiness. Nevertheless, care should be taken when considering the results and a check should be performed to verify whether the effect is due to stickiness or fiber quality parameters.

Relative humidity had a critical effect on yarn quality characteristics, and in particular by a change in the evenness counting for irregularities.

The figures in Table C-29 illustrate the relations described. A fitted line is only displayed in the figures below if a significant relation exists between the measured criteria and the stickiness level of the given cottons. In some figures, no significant relationship was detected

for any of the cottons, but one may appear to be highly significant for the cottons considered to show 'low to medium' stickiness. In these cases, the fitted line were drawn for these cottons. We give the analysis of variance results (drawn from Table C-29) in the upper right hand corner of the picture.

Figure C-74 shows a significant increase in Thin places in the RS yarn spun using cottons with a low stickiness level. For all humidity levels, the number of thin places showed a similar trend toward saturation when stickiness exceeded 20 sticky points. However, it was noted that more thin places occurred at lower humidities compared to other conditions.

Figure C-75 shows the relation the number of thick places plotted against RH% and stickiness. The only significant relationship was noted at 55% RH between the number of thick places and stickiness.

Figure C-76 shows that RH and stickiness had a significant impact on the number of neps (200%) in the yarn. However, a significant interaction induced a greater sensitivity to stickiness at higher humidity. It was also observed that the number of neps was higher when slightly sticky cotton was spun at 40% RH compared to the results when the same cotton was spun in 45 and 55% RH.

Moreover, a detailed analysis showed that stickiness increased the number of sticky neps (Stk, Figure C-77, Slide C-48), and also the number of fiber neps at all RH values (F, Figure C-78) under 45 and 55% RH conditions.

A significant relationship was noted solely between yarn strength and stickiness at 40%RH, even though the pattern at other humidities was similar (Figure C-79). This trend can be explained by the fact that stickiness induces irregularities that creates weak points in the yarn (as well as seed coat fragments, Krifa, 2001). This can be proven by counting the seed coat fragments present in the card fleeces (Figure C-80), where both counts (on yarn and on card fleeces) follow the same trend.

Figure C-81 shows that the cotton which appeared to show little stickiness contained many seed coat fragments that significantly affect yarn strength. Thus, the trend observed in Figure C-79 for the lower stickiness level cannot be considered as significant.

In most of the figures, a saturation effect was observed in the relations with stickiness. As stated above, interventions were made during the experiment to allow yarn production (these interventions were mainly performed for heavily contaminated cottons, Figure C-70 for instance), but was assumed indirectly to improve yarn quality. This hypothesis cannot be proven since it is impossible to predict what kind of defect we avoid by cleaning the spinning frame. However, this assumption can be proven by looking at the relationships between the main criteria (such as the number of thin and thick places and yarn strength) and stickiness: when few interventions are required to spin (non sticky cottons), we observe significant relations between the 'yarn quality criteria' and stickiness; as soon as the number of interventions increases, the relation between 'yarn quality criteria' and stickiness becomes non-significant and a saturation effect occurs.

The trend observed on the left of Figure C-79 does not continue to the higher level of stickiness since interventions and cleaning were performed to allow yarn production. Thus, we can assume that the number of irregularities was decreased artificially by the cleaning, and the number of weak points in the yarn decreased accordingly. However, this assumption should be checked using the new Tensorapid testing methodology and a new way to analyze the dataset (empirical quantile / quantile plot method, Krifa, 2000, 2001). This methodology can be used to analyze the interaction between fiber quality and/or contaminant on yarn

quality parameters.

C.5.3.2.2. *Quality of Open End spun yarns:*

An analysis of variance based on in the same design as for RS yarns was performed on the data. The results of this analysis are given in Table C-30. Counting data are assumed to follow a Poisson distribution because they should be evenly spread within the yarn because of all the mixing processes conducted while spinning. Thus, to normalize their variance, these counts transformed through a square root calculation.

Table C-30: Analysis of variance of the data collected in the RH experiment on OE yarns.

RH SUDAN YARN ANALYSIS, 3 HUMIDITIES, 7 COTTONS, Open End , 2 SETS

File: RH UT3 TITLE: RH SOUDAN UT3

NUMBER OF OBSERVATIONS: 84

DISPOSITIF DE L'ESSAI: SPLIT-PLOT 1/2

FACTEUR 1: 3 HUMIDITES 40% (40%), 45% (45%), 55% (55%)

FACTEUR 2: 7 COTONS 1 (AS02), 2 (AS09), 3 (AC1), 4 (AS04), 5 (AS10), 6 (AS20), 7 (AS05)

FACTEUR 3: 2 BLOCS BLOC 1 (B1), BLOC 2 (B2)

	CVM	RAC. THIN	RAC. THICK	RAC. NEPS. 280%	Hairiness YARN	ELONG YARN	TEN. YARN	CV TEN.
Rés. Suspects	2	2	2	2	2	0	0	2
F Hum.	0,1196	0,0287	0,0530	0,0037	0,2111	0,0093	0,6067	0,1901
ETR 1	0,75	0,55	0,85	0,41	0,66	0,23	,42	0,59
CV 1 (%)	4,8	11,1	9,0	5,3	12.2	,3,2	4,2	5,6
F Cot.	0,0823	0,0124	0,0006	0,0000	0,1473	0,0000	0,0000	0,0000
Int. H×C	0,2529	0,0102	0,0014	0,0000	0,3342	0,0000	0,4137	0,2329
ETR 2	0,57	0,57	1,16	0,55	0,41	0,08	0,17	0,66
CV 2 (%)	3,7	11,4	12,2	7,2	7,5	1,1	1,8	6,4
Moy. Gén.	15,49	4,99	9,46	7,73	5,47	7,20	9,90	10,41
40%	15,16	4,39 b	8,40	7,43b	5,56	7,86 a	9,80	10,26
45%	16,12	5,94 a	9,72	6,33c	5,76	6,78 b	9,97	10,18
55%	15,20	4,65 b	10,26	9,42a	5,09	6,95 b	9,94	10,78

	CVM	RAC. THIN	RAC. THICK	RAC. NEPS. 280%	Hairiness YARN	ELONG YARN	TEN. YARN	CV TEN.
1 (AS02)	15,51	4,96 ab	10,77 a	9,80a	5,53	7,43 c	9,89 c	10,42 ab
2 (AS09)	16,15	5,83 a	9,54 ab	6,47c	5,22	6,69 f	9,19 e	11,41 a
3 (AC1)	15,33	5,21 ab	10,71 a	9,39a	5,13	7,19 d	11,06 a	8,59 c
4 (AS04)	15,40	4,68 b	8,18 bc	5,97cd	5,73	6,99 e	9,39 de	11,10 a
5 (AS10)	15,64	5,16 ab	9,57 ab	7,95b	5,71	6,76 f	9,52 d	11,44 a
6 (AS20)	15,01	4,50 b	7,42 c	5,31d	5,42	7,76 a	10,21 b	9,84 b
7 (AS05)	15,36	4,64 b	10,01 ab	9,22a	5,54	7,57 b	10,06 bc	10,06 b

The relationship was only significant at 55%RH (Figure C-82).

Figure C-83 shows a significant relationship between the number of thick places and stickiness at 55%RH, while no significant relationship was noted for other RH conditions.

Figure C-84 shows a significant relationship between the number of neps and stickiness at 55%RH, while no significant relationship was noted for other RH conditions. The detailed analysis of the neps present in the yarn provided more information concerning the type of neps that had increased. Figure C-85 and Figure C-86 indicate that both fiber neps (F) and sticky neps (Stk) contribute to the increase in the total number of neps in the OE yarn. It should be mentioned that the number of neps also increased significantly with stickiness at 40%RH but to a lesser extent.

Figure C-87 shows that the cotton appearing as no sticky contains a lot of seed coat fragments that significantly affects yarn strength. Thus the observed trend in Figure C-88 for lower stickiness level cannot be considered as significant.

Similar trends were observed for yarn strength and stickiness relations in both OE and RS yarns (Figure C-88). Again, stickiness increased the number of irregularities in the yarn, causing an increase in the number of weak points, which decreased yarn strength.

Figure C-89 and Figure C-90 show the percentages of each type of nep in RS and OE yarns respectively. Seed coat fragment contribute for a large part to the neps observed. Sticky neps also increase as RH% increases.

C.5.4. Conclusion

As proven in the real-scale experiment, stickiness affects both productivity and quality parameters. Thus, stickiness increases the number of cleanings and interventions during spinning.

The data collected during this experiment also provide new information about the effect of ambient conditions on yarn production. Stickiness increases the number of human intervention, especially when spinning is conducted at high relative humidities. During this experiment, our interventions were designed to allow yarn production to continue, and thus affected some yarn quality parameters. Trends were nevertheless noted for most of the parameters vs stickiness. The slopes of these relations are clearly affected by ambient conditions during spinning.

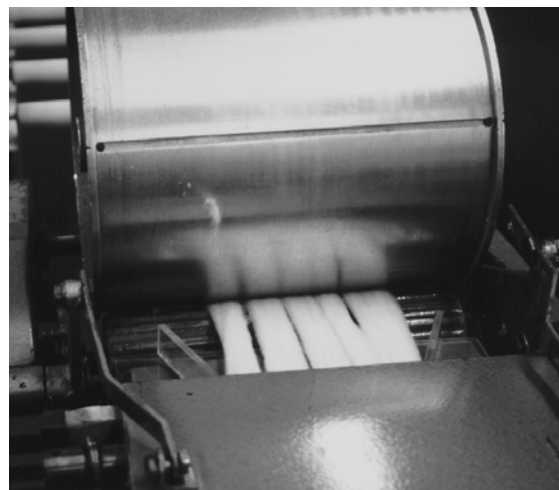
As a global conclusion, spinning under low humidity conditions will avoid most of the problem induced by stickiness, even if some yarn quality parameters are affected by such conditions.



Slide C-35: Mini-carding and collecting system.



Slide C-36: Drawing-frame and collecting system in cans.



Slide C-37: Feeding system on the 2nd pass of the drawing frame.



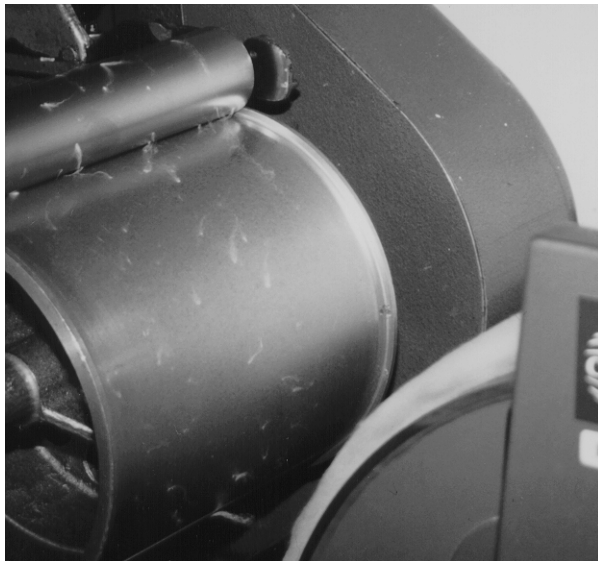
Slide C-38: Drafting zone of the drawing frame.



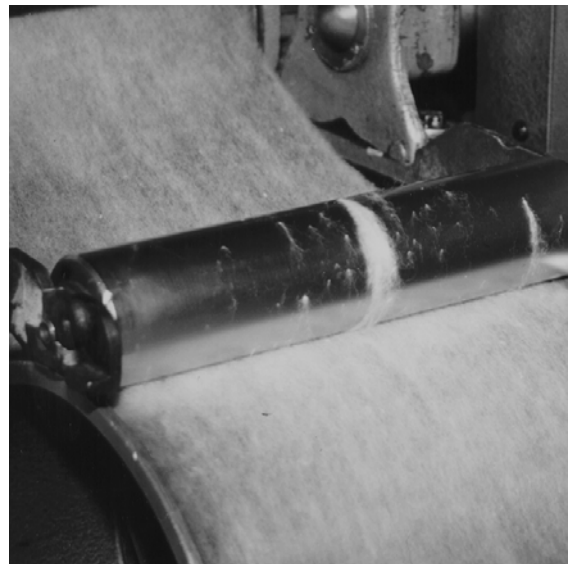
Slide C-39: Ring spinning frame during a stickiness observation phase.



Slide C-41: Example of a stickiness-induced problem.



Slide C-40: Example of a stickiness-induced problem.



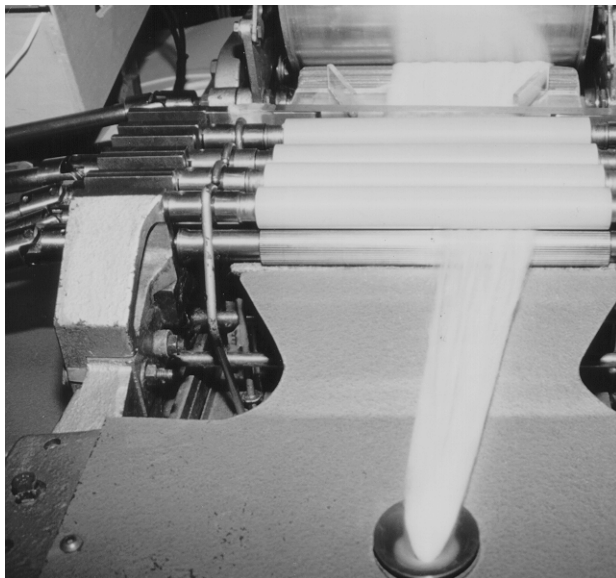
Slide C-42: Example of a stickiness-induced problem.



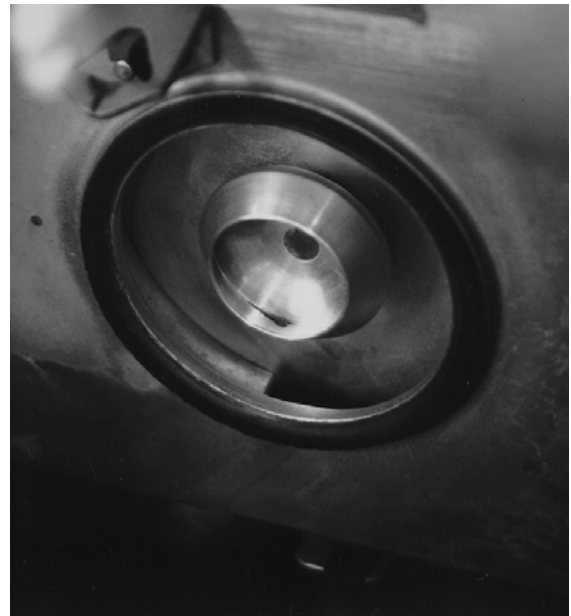
Slide C-43: Example of a stickiness-induced problem.



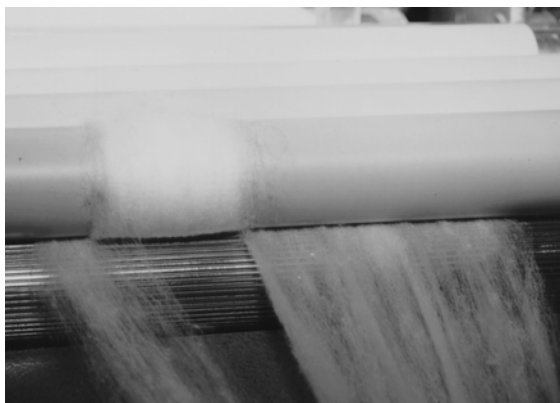
Slide C-46: One sticky point on a rotor.



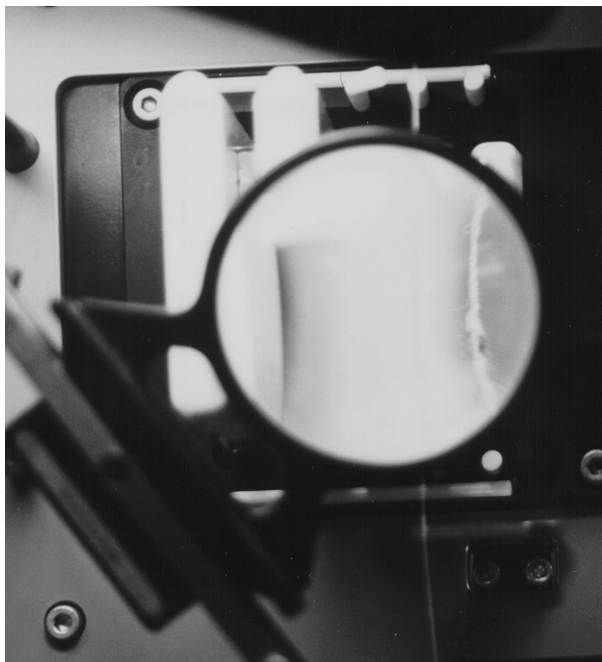
Slide C-44: Example of a stickiness-induced problem.



Slide C-47: One sticky point on a rotor.



Slide C-45: Rolling-up at the drawing frame level.



Slide C-48: Examination of a nep on the evenness tester.

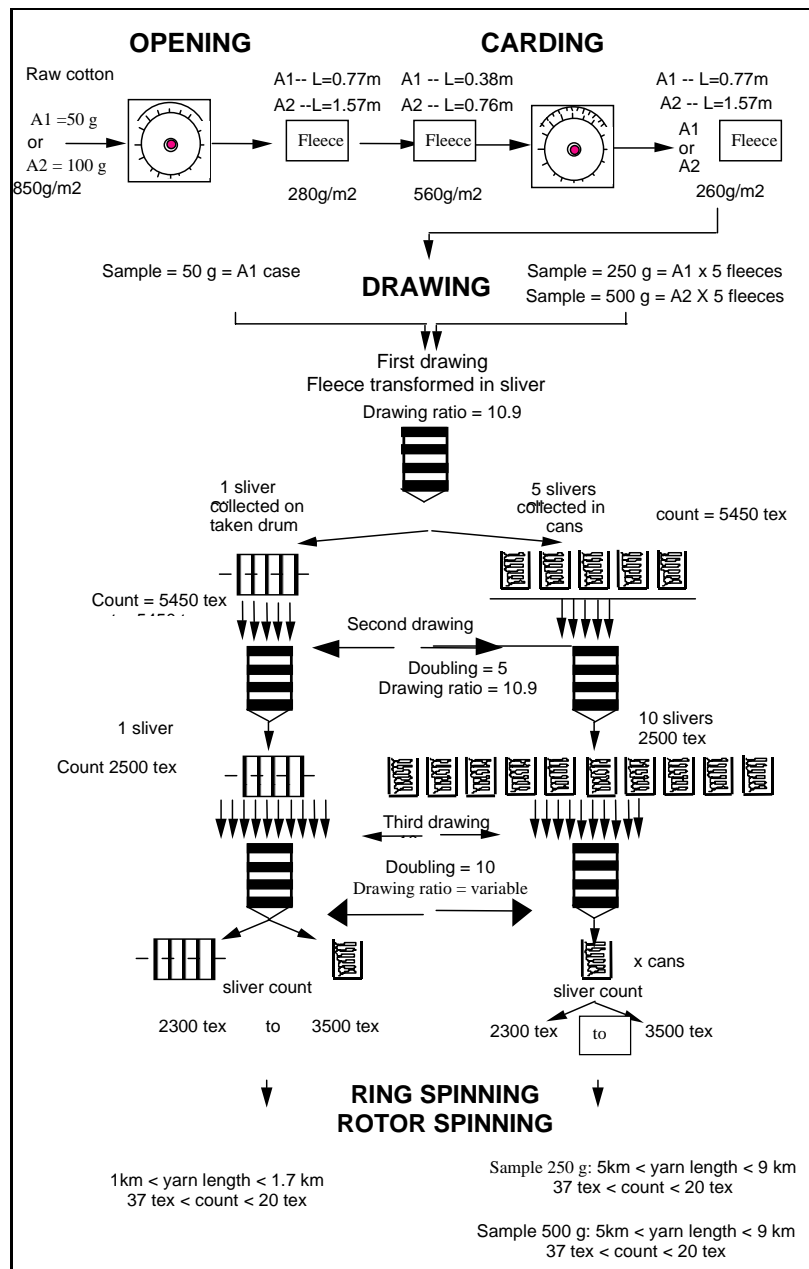


Figure C-64: Spinning procedure in a micro-spinning test.

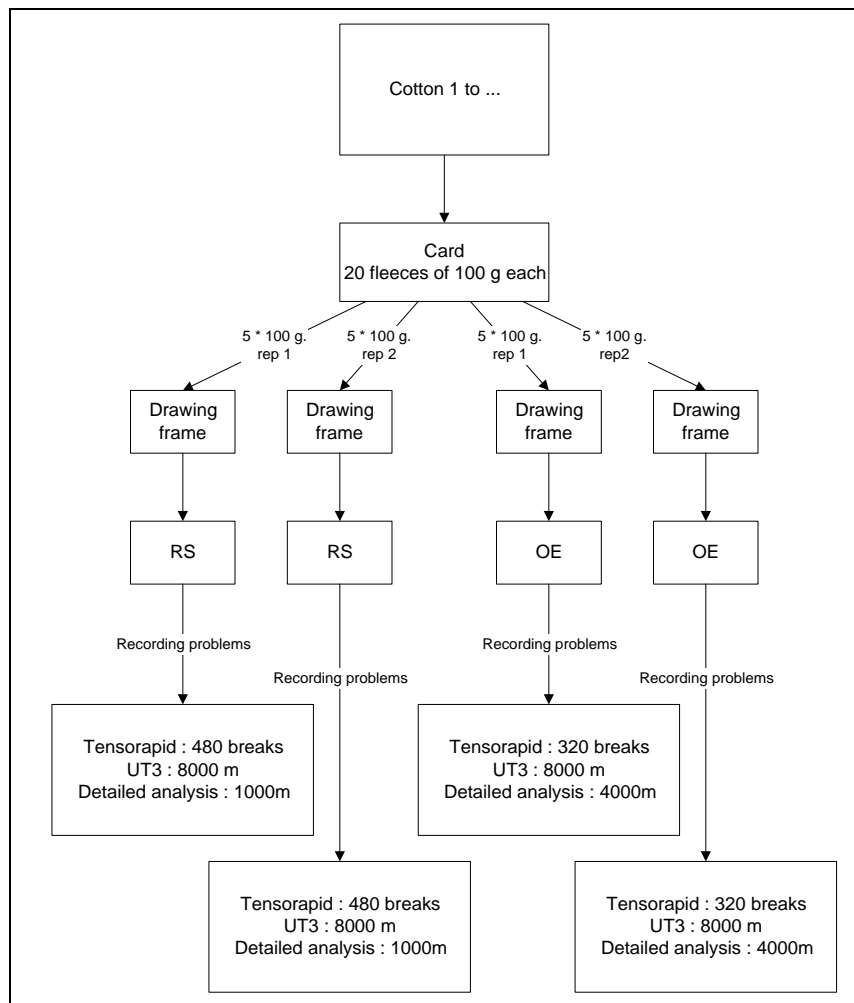


Figure C-65: Organization of the test from raw cotton to yarn testing.

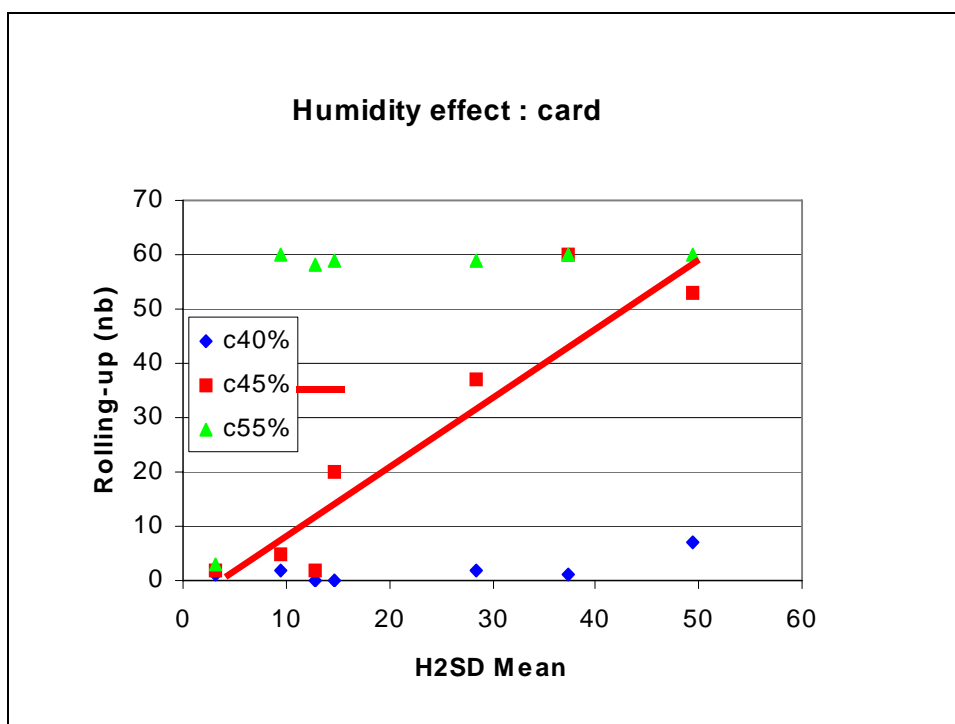


Figure C-66: Effect of stickiness on rolling-up at the card level.

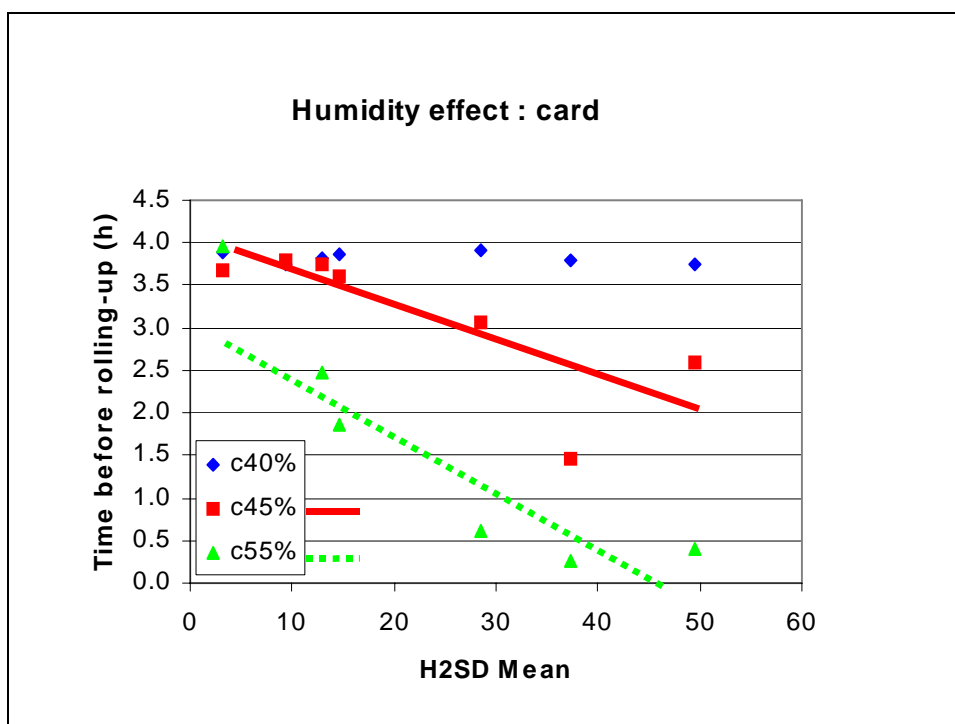


Figure C-67: Time to onset of rolling-up at different RH% values.

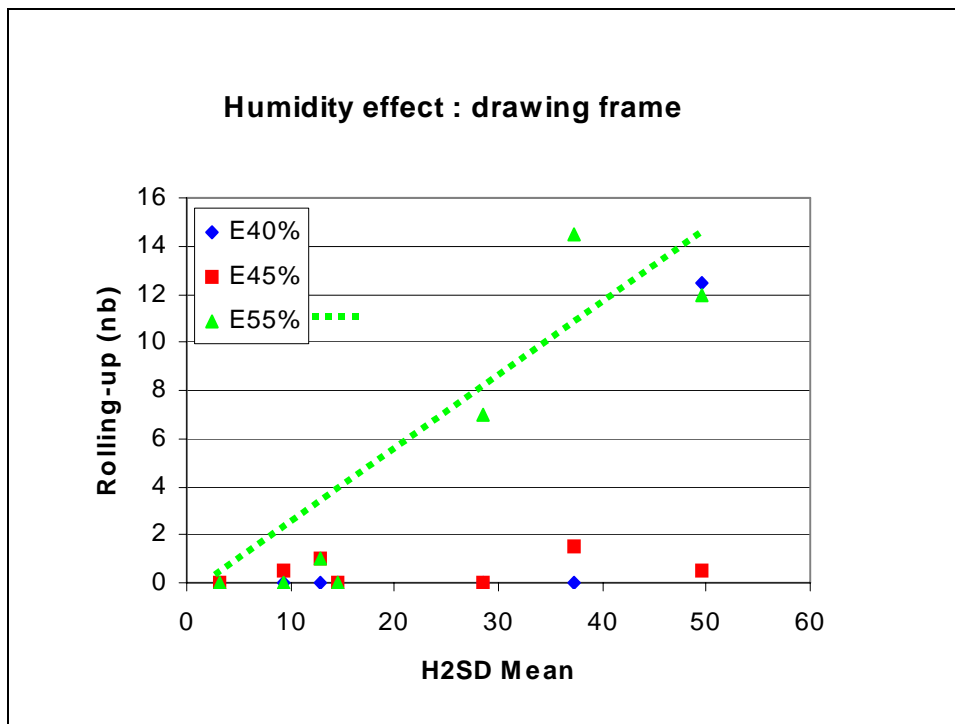


Figure C-68: Number of rollings-up at the drawing frame level vs stickiness.

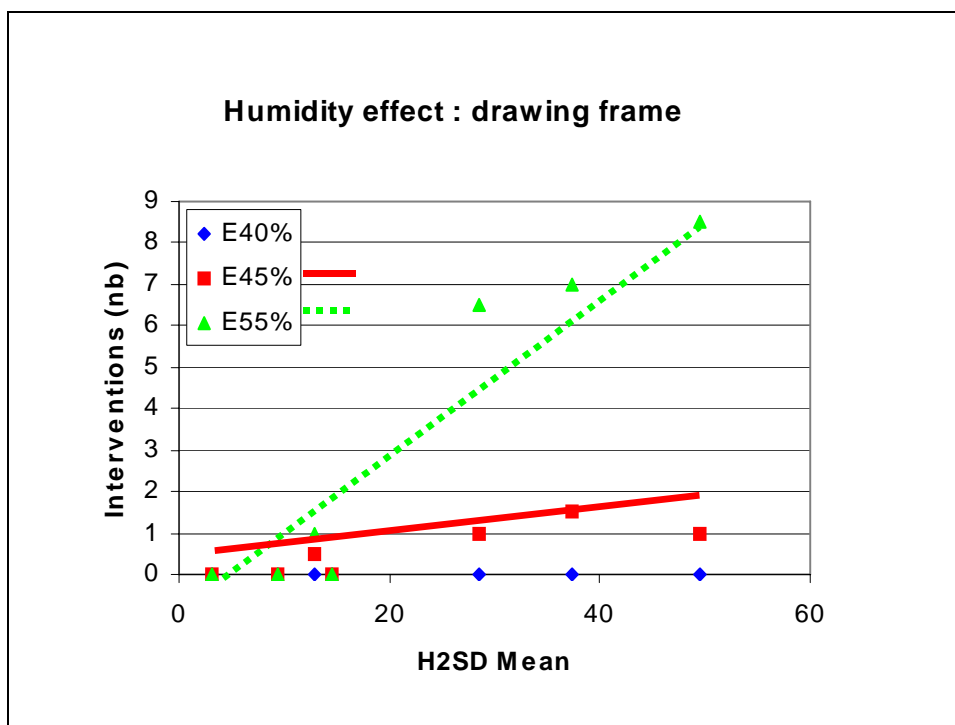


Figure C-69: Number of interventions on the drawing frame vs stickiness.

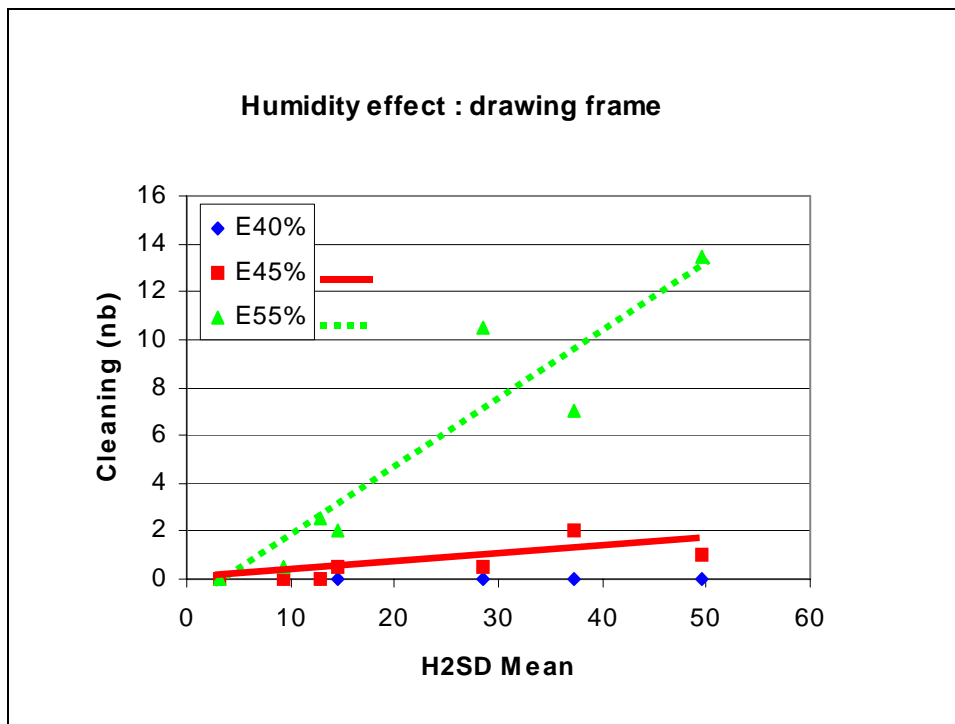


Figure C-70: Number of cleanings required on a drawing frame vs stickiness.

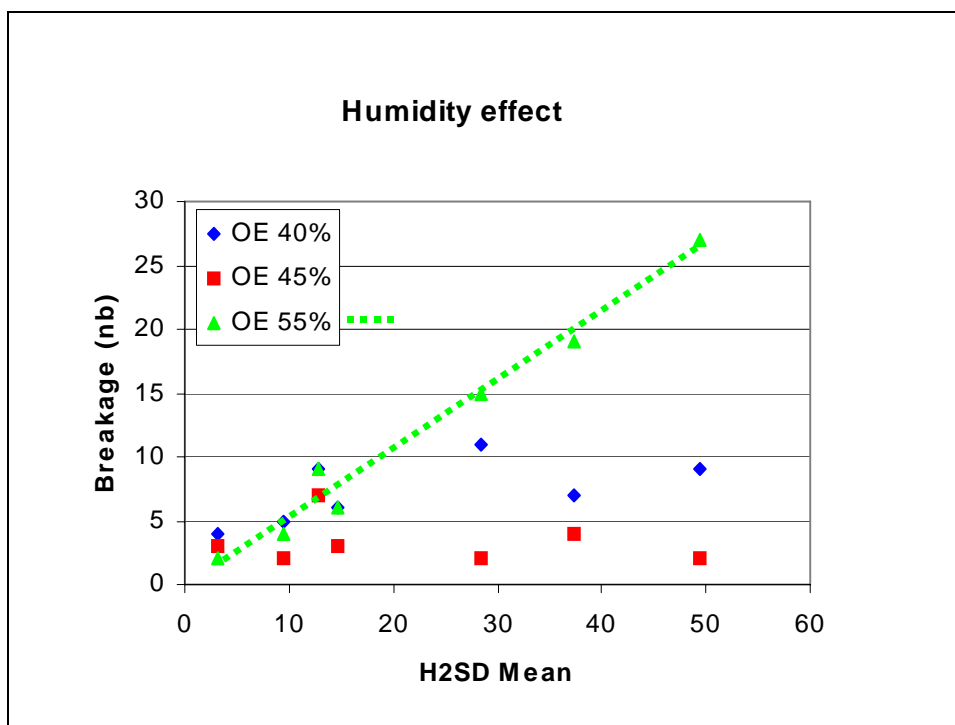


Figure C-71: Breakages vs stickiness on the OE machine.

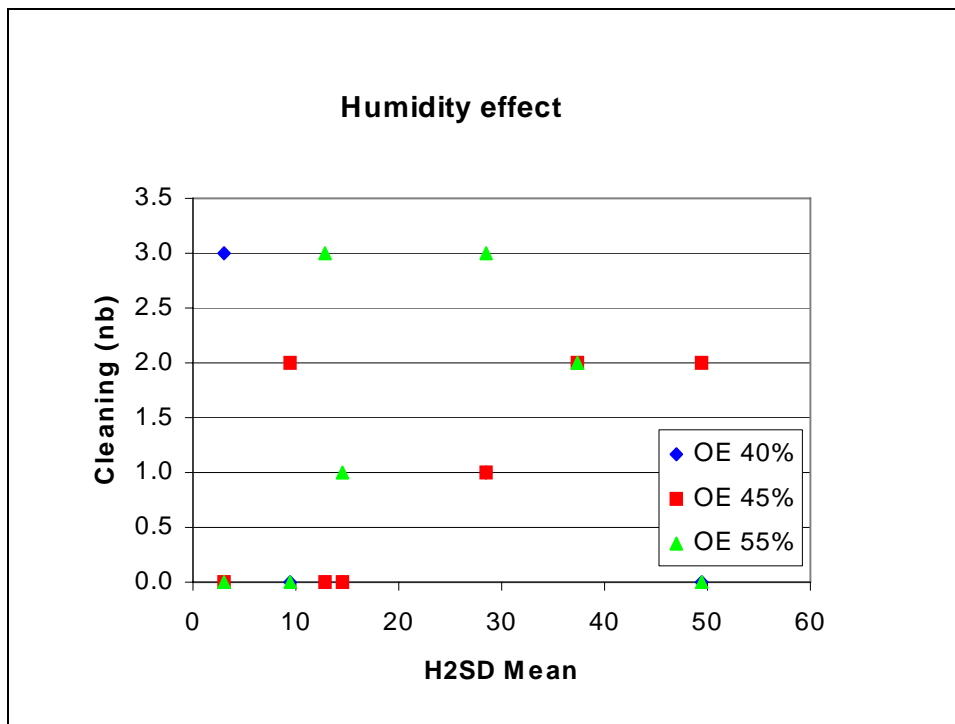


Figure C-72: Number of cleanings on the OE machine vs stickiness.

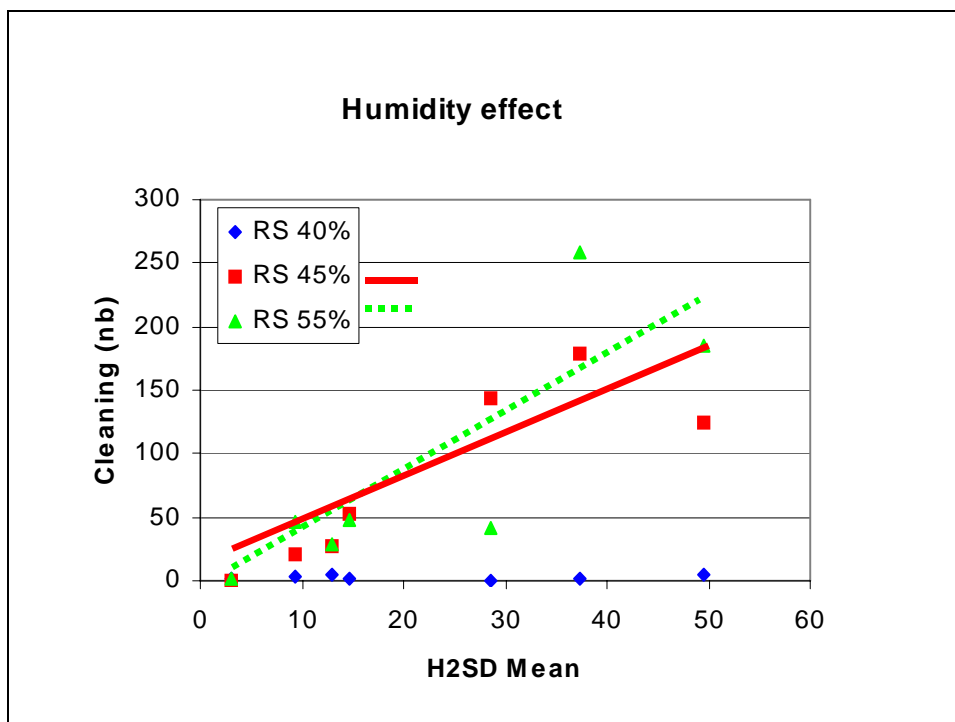


Figure C-73: Number of cleanings on the RS machine vs stickiness.

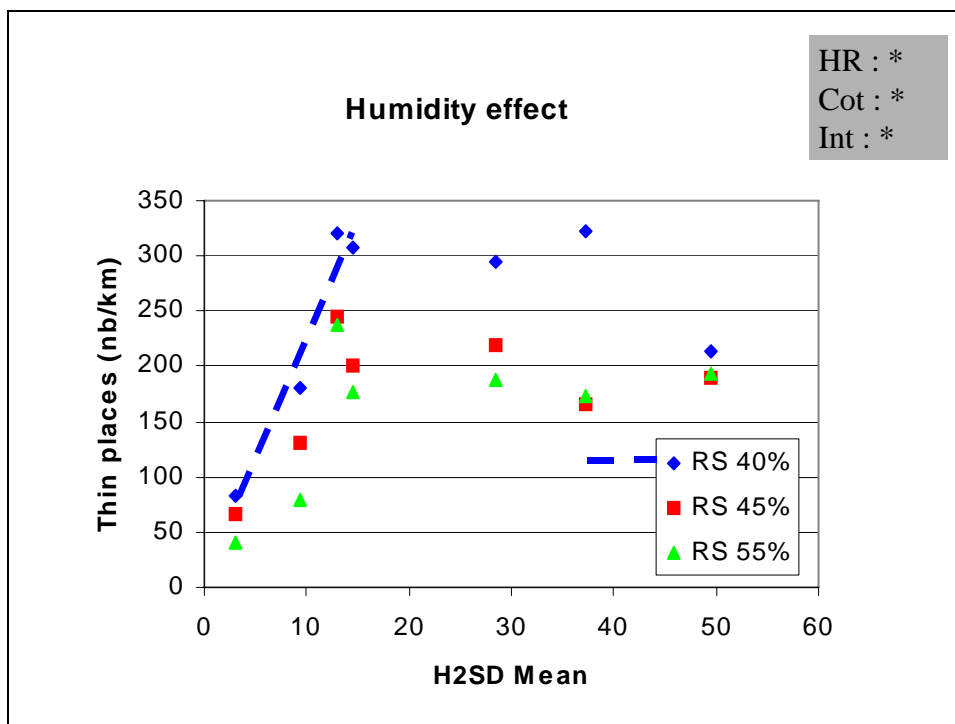


Figure C-74: Number of thin places vs stickiness under different RH% conditions.

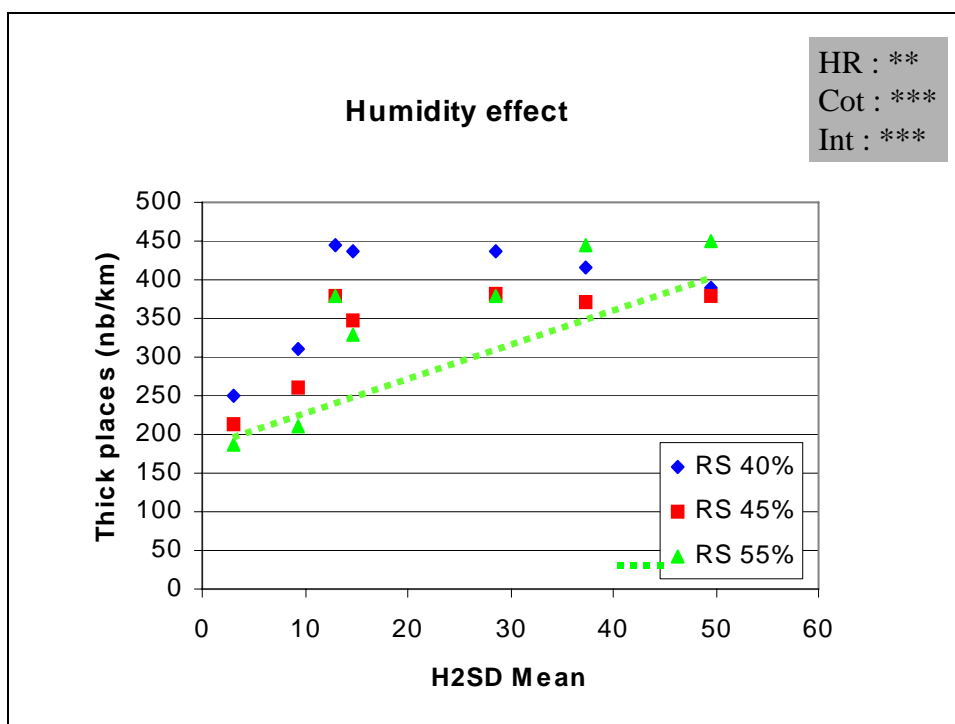


Figure C-75: Number of thick places under different RH% conditions and stickiness levels.

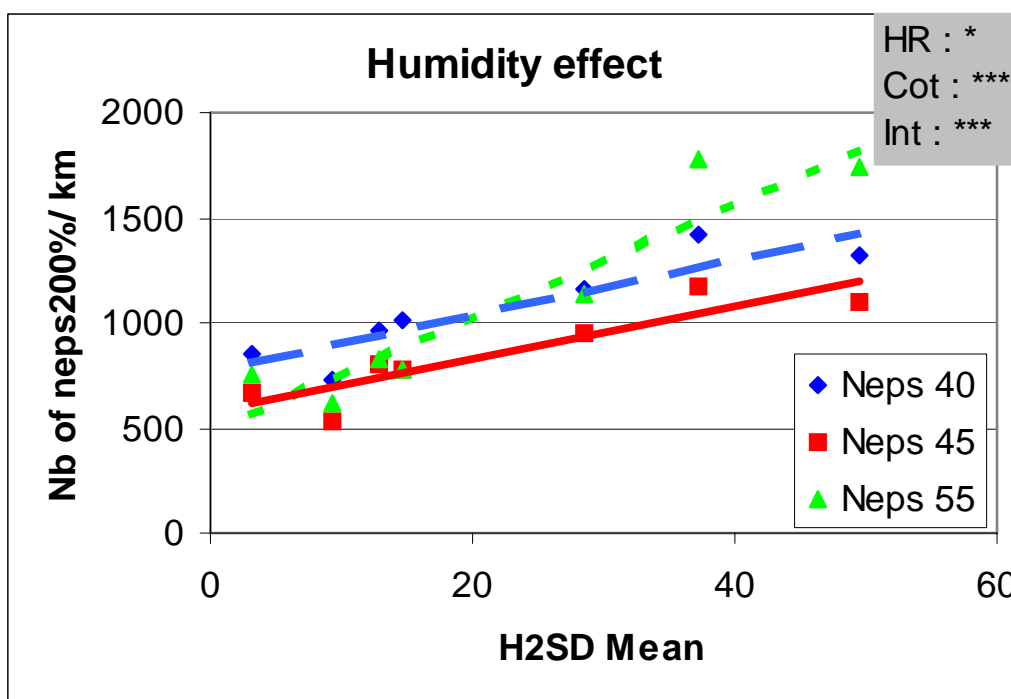


Figure C-76: Number of neps under different RH conditions and stickiness levels.

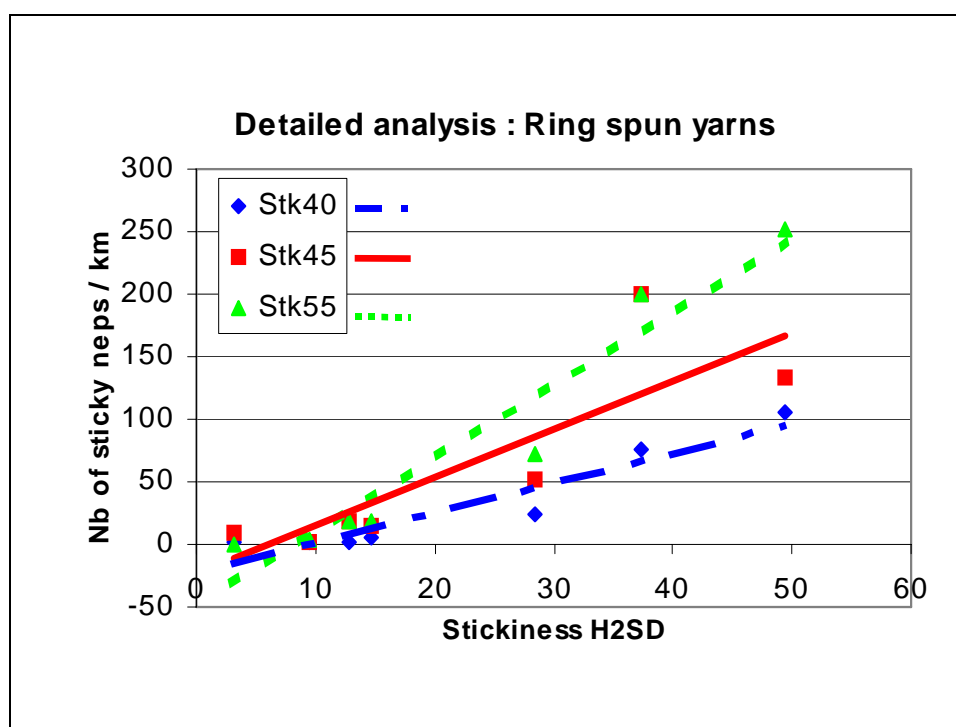


Figure C-77: Number of sticky neps, detailed analysis.

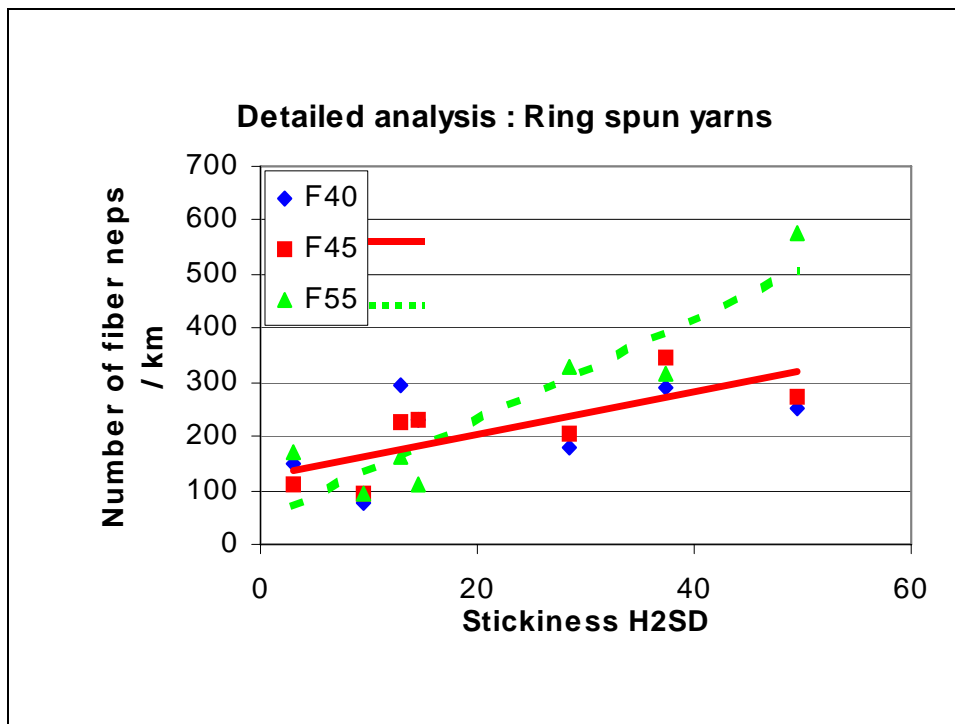


Figure C-78: Number of fiber neps, detailed analysis.

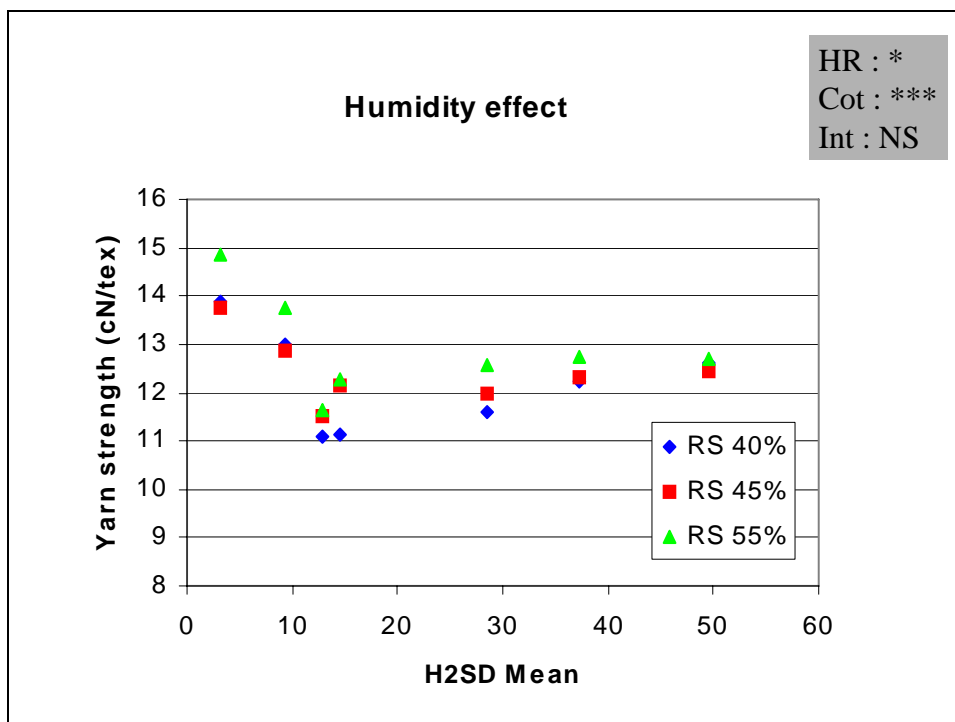


Figure C-79: Effect of RH% and stickiness on yarn strength.

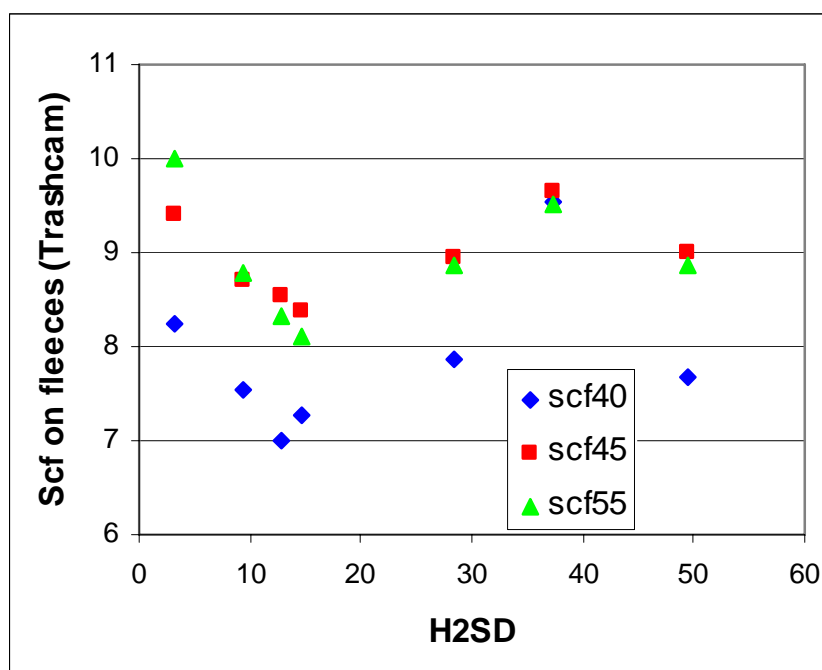


Figure C-80: Number of seed coat fragments in the card fleeces as counted by Cirad's Trashcam device.

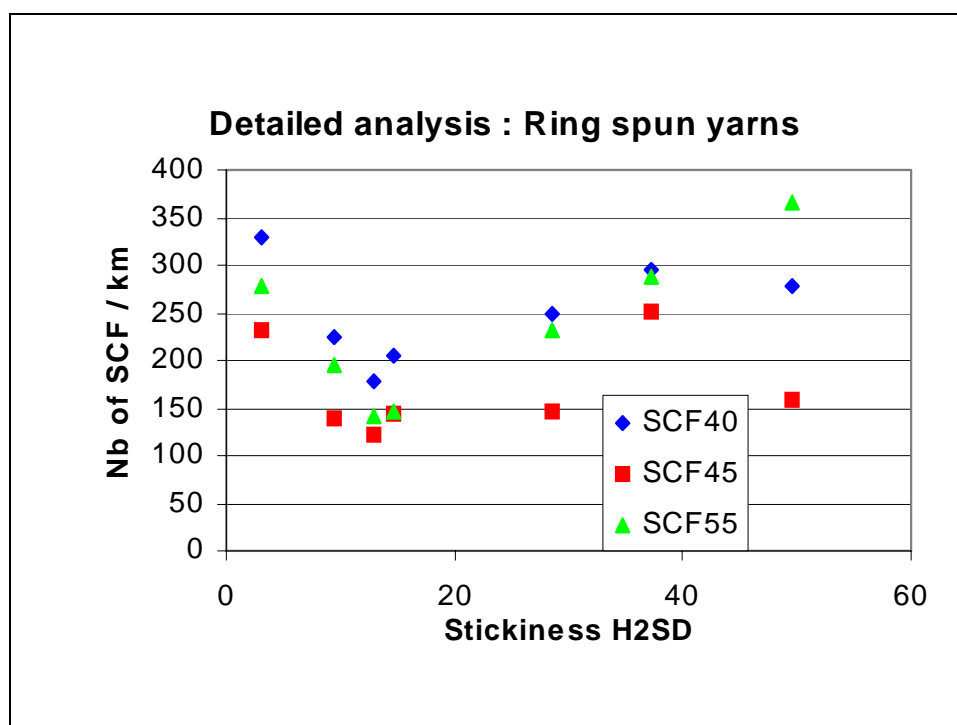


Figure C-81: Detailed analysis on RS yarns: seed coat fragments content.

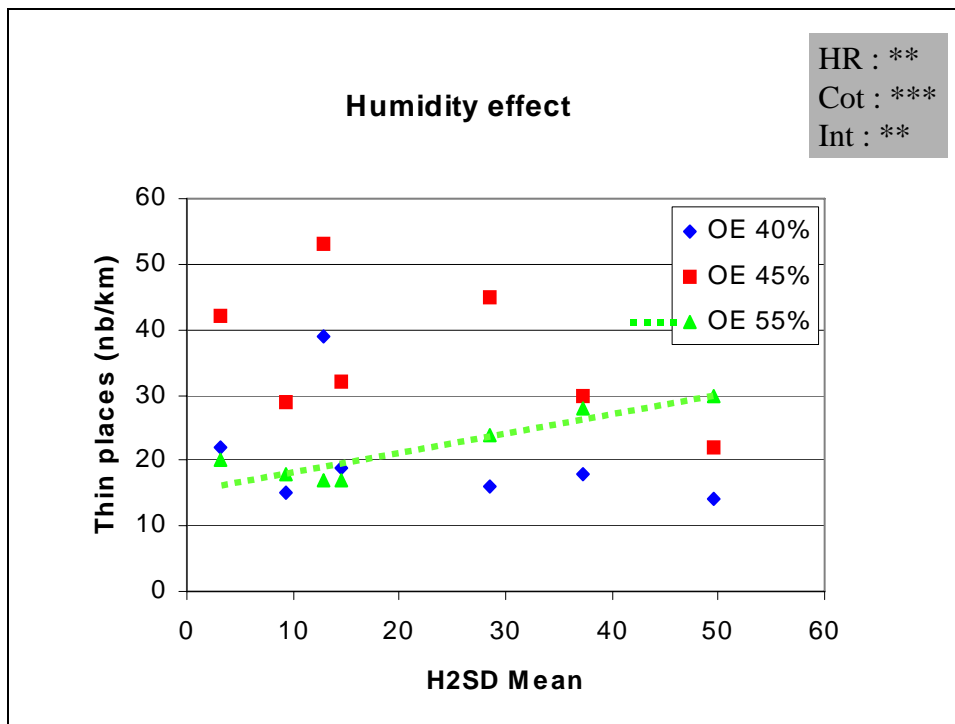


Figure C-82: Effect of stickiness and RH% on the number of thin places.

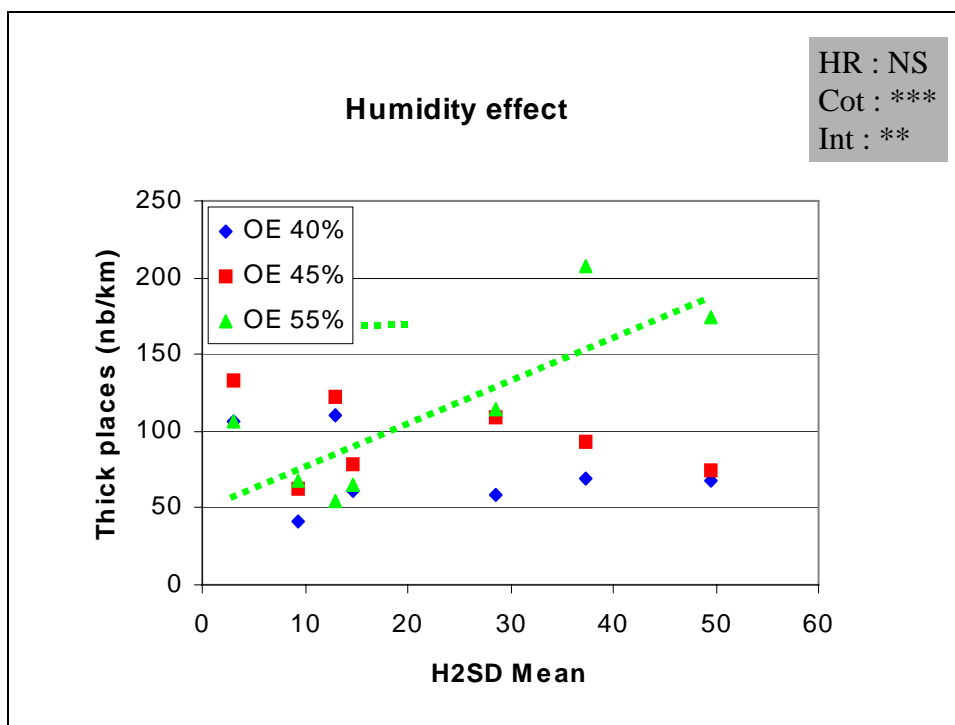


Figure C-83: Number of thick places for different RH% and stickiness values.

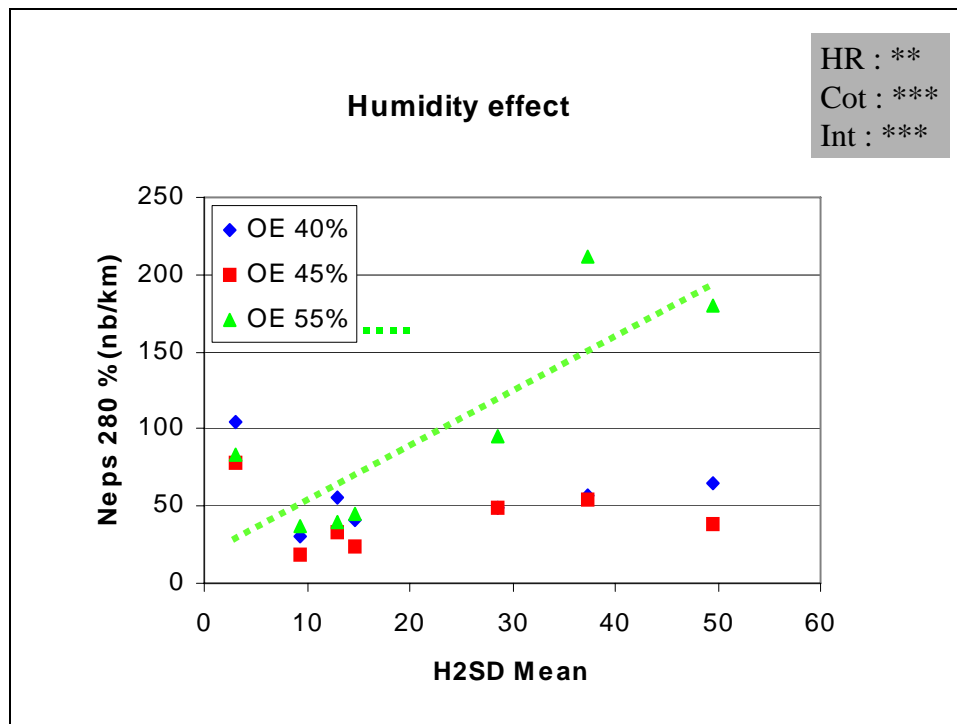


Figure C-84: Number of neps 280% at different RH and stickiness values.

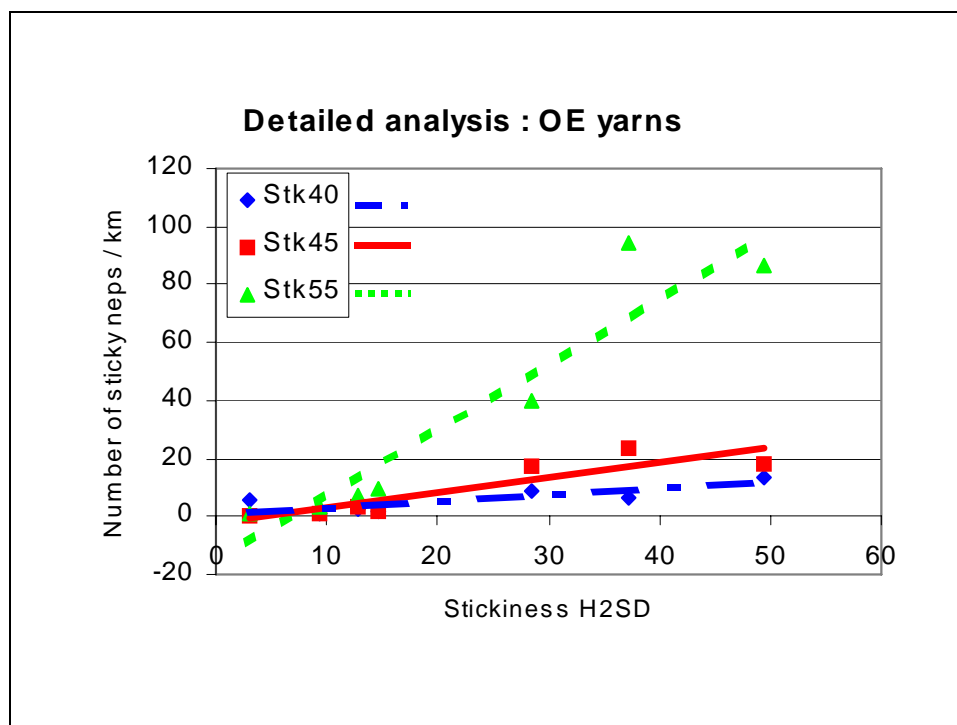


Figure C-85: Number of sticky neps, detailed analysis.

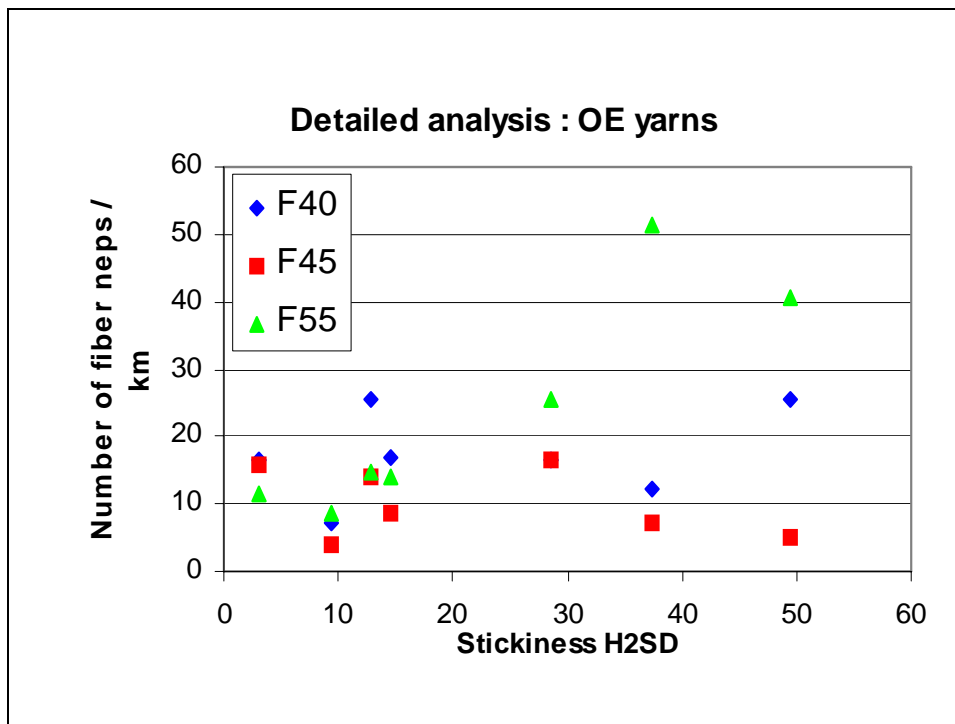


Figure C-86: Number of fiber neps, detailed analysis.

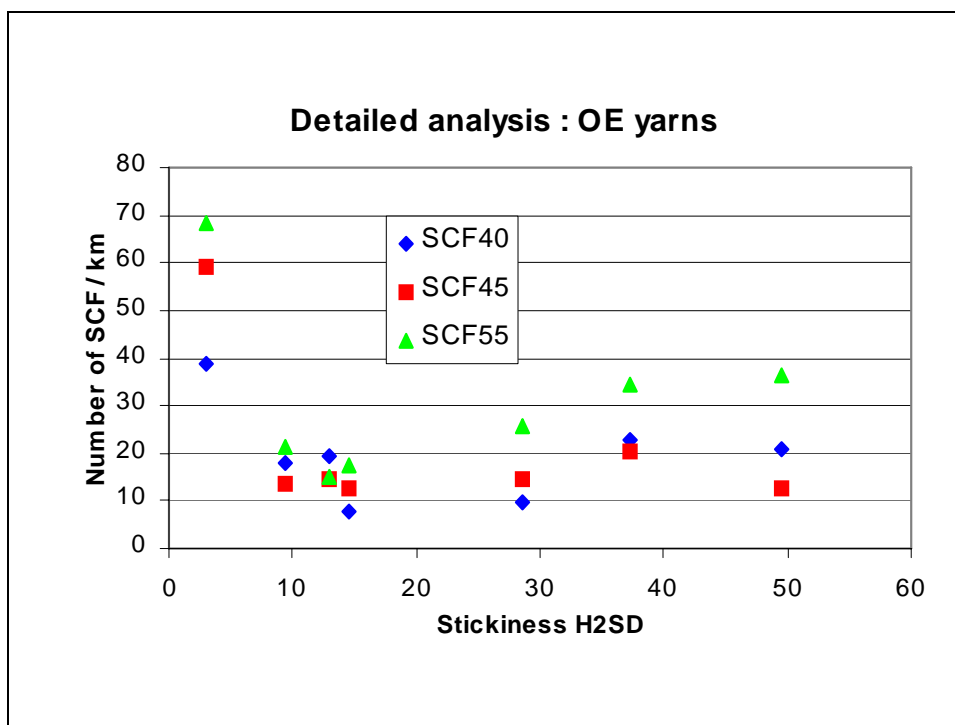


Figure C-87: Detailed analysis of OE yarns: seed coat fragments content.

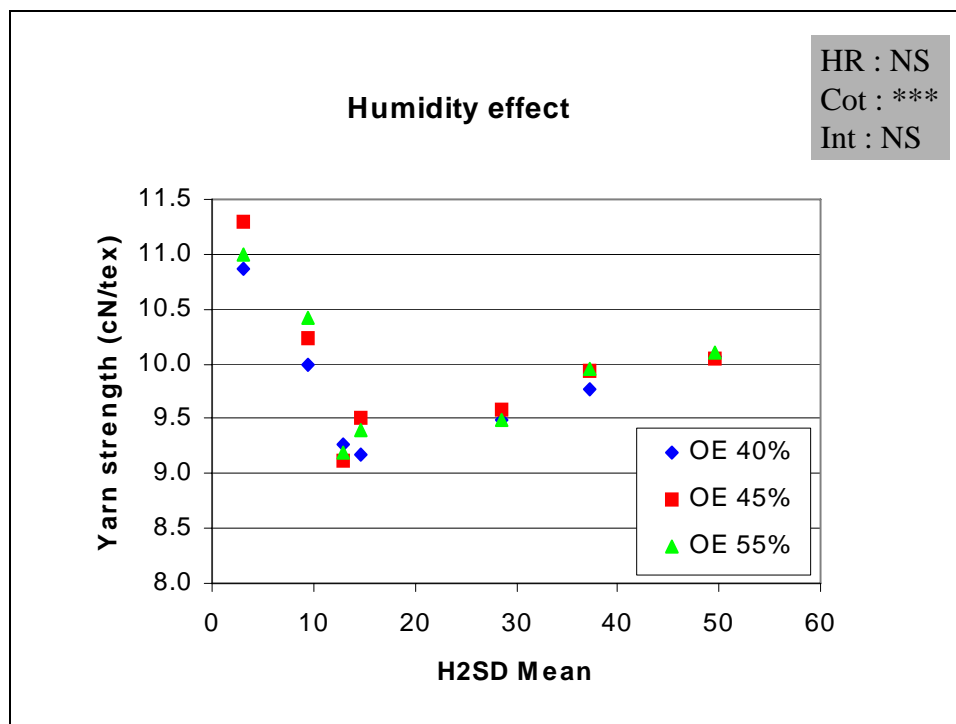


Figure C-88: Yarn strength at different RH and stickiness values.

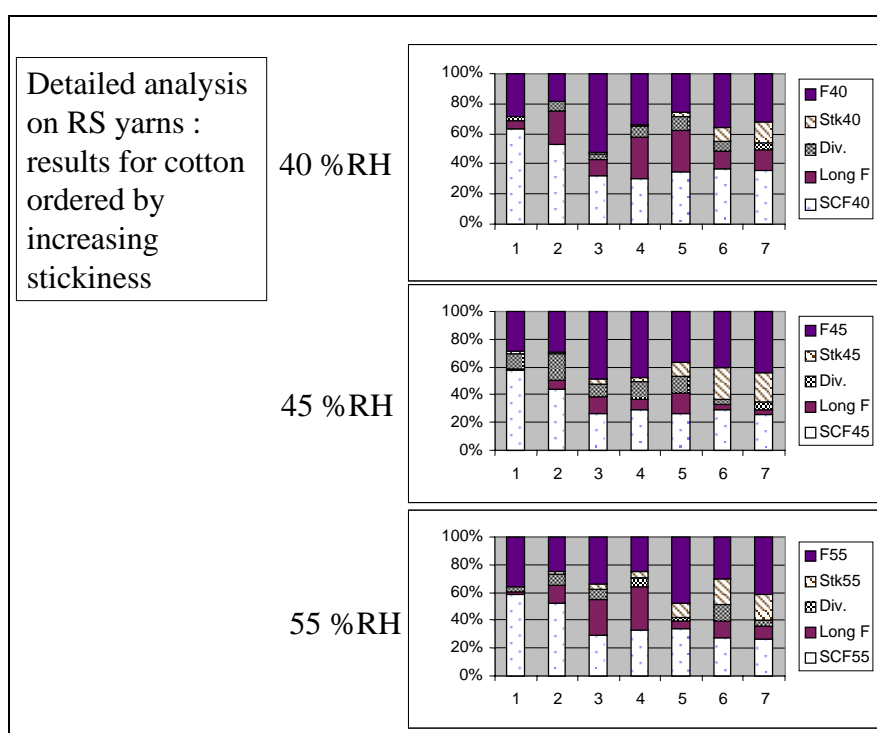


Figure C-89: Results for RS yarn neps: detailed analysis at different RH%.

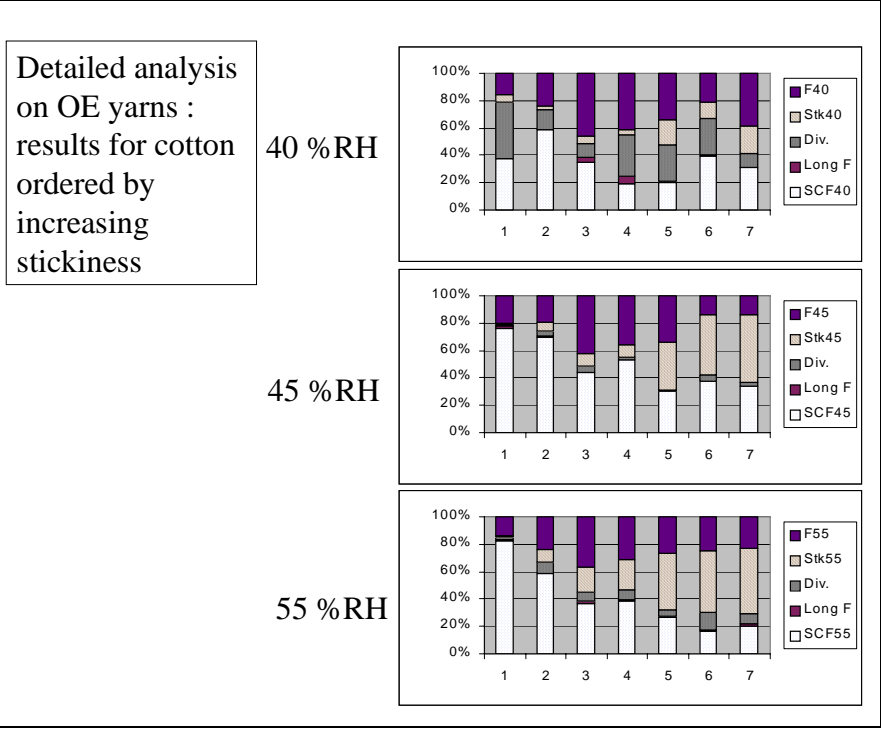


Figure C-90: Results for OE yarn neps: detailed analysis at different RH%.

C.6. General conclusion for component B

Component B was designed to evaluate the impact of stickiness on spinning productivity and quality parameters. The hope was to highlight a stickiness limit below which only manageable problems would occur during spinning while above it spinners would encounter real problems that could lead to financial losses. The intention was to use this ‘spinning limit’ as an evaluation threshold to fix rules in the commercial trading of cotton. Here the results from component A: the cotton producers being able to fix his own litigation risk as deduced from the within-bale and within lot variability, it would have been possible to fix the classification threshold to be respected in the classing offices.

From component A, we learned that it is difficult to derive a statistical law to match the data observed for all cotton produced in Sudan.

An industrial spinning test confirmed that stickiness induces disruption during spinning and leads to both productivity and quality losses. In general, this was already well known. However, we did expect to encounter a flat zone, even if a low degree of stickiness is present in the fibers, no significant disruption would occur. This is illustrated in Figure C-91. Then, above a given stickiness limit, which could serve as evaluation threshold, increasing problems would appear as stickiness increased.

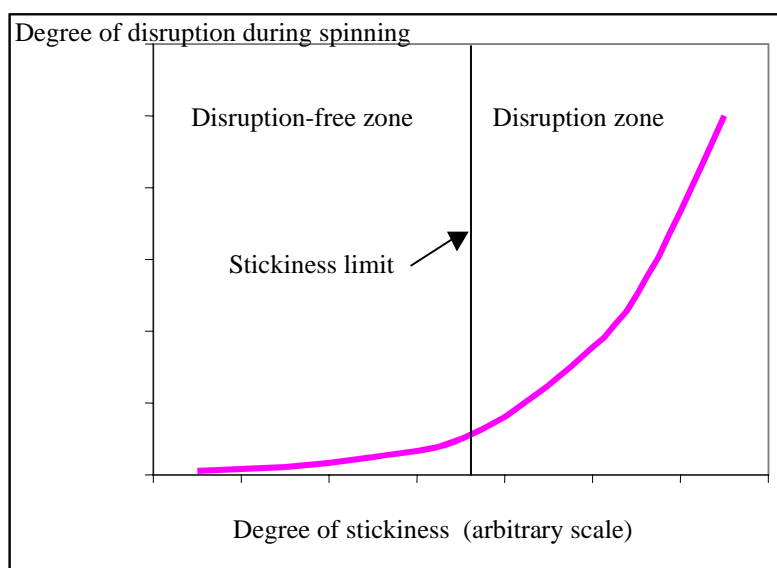


Figure C-91: Expected relation between stickiness and disruptions.

From a practical standpoint, it was first necessary to find the best estimator of stickiness. This was done by taking account of the principle, the precision, the cost and the time consumption of the measuring method available in this project. Three methods, SCT, HPLC and H2SD were compared for their ability to predict problems during spinning both in terms of productivity and yarn quality.

The H2SD measuring device was retained because its results correlate more closely with all quality and productivity parameters. However, it should be noted that some sugar contents as measured by HPLC also correlated well with some parameters since they are directly related to the sugars that cause specific problems during spinning. SCT was not chosen, even if some relations are shown in this report, since a substantial operator effect was possible on the reading as seen in ‘Component a’ of this project.

After classification of the sticky points into size classes corresponding to “small”, “medium” and “large” on H2SD, these experiments did not show any significant trend with the criteria

recorded. This does not mean that this variable has no effect on the spinning process. Further development work is ongoing to improve the H2SD's image analysis system so that the measured size will be closer to that actually in the cottons. A more accurate measure of sticky point size might mean that all the conclusion of this research work would have to be revised. Indeed, it is probable that a change in sticky point size distributions may appear, and that this change may affect the existing relations with the spinning process. In this case, it may be possible that the different sticky point size classes will explain specific productivity or quality problems in the spinning mill.

The conclusions drawn in this document are highly dependent on the testing conditions of industrial scale experiments. Thus, the type of machines, their brand (assuming specific know-how by each textile machinery manufacturer), their settings, the ambient conditions, the type of work (extensive or intensive labor), the automation level, ... can all play important roles in the way stickiness affects their operation, and therefore in the relations that have been described.

NB: Any deductions made from the graphs given in this report, are only representative of our test conditions on specific samples.

From the industrial scale experiment and its specific, restricted operating conditions, we learned that, as expected, the flat disruption free zone may exist for some quality and productivity parameters. However, its range may vary in width on the stickiness scale as measured by H2SD. This means that some productivity and quality parameters may be affected at low stickiness levels, while other parameters will not be as sensitive to a change in stickiness.

A specific stickiness level was found at the card where the fibers are cleaned almost individually. Here, the effects of stickiness were most marked and rendered impossible the carding of highly contaminated cottons.

This research cannot result in setting a critical threshold for worldwide spinning since the machine used are so different that some countries are specialized in processing heavily contaminated cottons, while other do not accept even traces of stickiness among the processed fibers.

Thus, if a classification procedure is implemented, classification threshold(s) will have to be set for every customer at a level that depends on his ability to process fibers of a given stickiness. This would be described in some kind of agreement between two parties. The organization of such a classification will lead to changes in the way bales are grouped according to homogeneous stickiness level.

Complementary experiments based on changes in relative humidities (RH) indicated possible solutions to combat stickiness. These experiments showed that productivity parameters improved by lowering the relative humidity level and some quality parameters were also improved or stabilized compared to the normal conditions met in the spinning mills. A clear effect of RH and stickiness on the micro-spinning process was observed as expected. An increasing first effect is observed on some productivity parameters for both ring and open-end micro-spinning when ambient conditions are becoming more humid in the spinning laboratory. It also exists an increasing effect of stickiness on yarn quality parameters which goes in the direction of worse quality for almost well-known parameters.

Since it is difficult to choose a range of cotton that differ only by their stickiness level, fiber quality parameters may interact with the conclusions drawn in this experiment. However, fiber quality was fairly homogeneous and most of the effects observed in this study can therefore be considered as mainly dependent on stickiness and the ambient conditions.

Yarn production sometimes required human interventions which had consequences on yarn quality. This is why we observed some saturation effects in the relationships between stickiness characteristics and RH conditions.

Nep numbers increased with stickiness and relative humidity as shown by the evenness tester that separated the different categories of neps: this increase was mainly induced by the creation of sticky and fiber neps in the yarn.

Mixing a sticky cotton with a non-sticky cotton is an appropriate method to decrease the stickiness level of the mix. A simple formula was derived from the data. However, this formula is limited since it is no longer predictive when stickiness becomes high. Two questions remain unsolved:

- large sticky points can be split into different smaller parts during the mixing operations: do these smaller points have the same behavior as 'natural' small points in terms of consequences on the spinning process ?
- is this formula valid for more than 2 constituents in the mix ?

This experiment was based on relatively small amounts of fibers which, after the mixing operation, showed comparable sticky points distributions (dispersion index 1.7) to that observed in industry (dispersion index 1.9).

It is essential to take this information into account when preparing cottons with a range of stickiness levels to check and/or calibrate the measuring devices. The mixing operation is increasingly difficult when cottons with low stickiness levels are mixed with a non-sticky cotton.

To sum up, it is now possible to relate the results from the two first components of this project. Methodologies were developed to evaluate the within-bale variability of stickiness, then evaluate, if conditions remain stable, the number of samples taken per bale and the number of readings required on the measuring devices.

Next, statistical methodology was described to establish thresholds to categorize bales in different lots according to their stickiness level. In this report, the methodology was applied to 2 category classification for the separation of sticky cottons from non-sticky cottons. The method can also be applied to form more than 2 stickiness classes.

From the spinning experiment, we learned that no typical, single threshold can be set since each mill in the world has its own typical machinery and/or knowledge and/or economical conditions that enable some to process heavily contaminated fibers while others cannot.

In conclusion, classification thresholds can only be defined between producers and users in accordance with negotiated agreements where the most important classification procedure steps can be discussed depending on the price of the material, the classification, etc ... with respect to standards (meaning: documented methods). This approach complies with the fact that all standards mention that if test conditions differ from the recommended method, this must be mentioned in agreements between the parties.

COMPONENT C

Evaluation of the financial viability of the process, training, dissemination of project results through presentations, publications and technology transfer

Chapter D. Component C: Evaluation of the financial viability of the process, training, dissemination of project results through presentations, publications and technology transfer

On the basis of relevant financial and production data obtained in the course of the project, a comprehensive financial analysis was prepared in the third project year. This analysis established the financial and economic viability of the processes using the Sudan situation as a practical case study. A model for making projections of benefits to other countries wishing to adopt the processes is included in the report. The risks are also clearly stated.

Project achievements were documented in regular progress reports to the ICAC and the Fund, but above all in technical reports presented at relevant meetings organized in the framework of global ICAC meetings or in workshops and seminars organized by other organizations (e.g., the African Cotton Research Network-ACREN, the Conference des Responsables de la Recherche Agronomique Africain-CORAF and the Interregional Cooperative Research Network on Cotton for the Mediterranean and Middle East Regions).

In order to provide hands-on exposure to the methods used in the project, be it with regard to activities related to the determination of the levels of stickiness in cotton bales or to the processing of sticky cotton, a provision is made in the project budget for a training/visiting programme in the third project year for technicians from interested developing countries. The modality for the programme as well as the determination of the number of participants were determined by the PEA and the Supervisory Body in close consultation with the Fund in the course of the second project year. A provision has also been made for an international workshop to be organized in Sudan towards the end of the project for dissemination of the project results. Given the close link with the earlier mentioned Fund-financed Integrated Pest Management project in Israel, Egypt, Ethiopia and Zimbabwe, representatives from that project are envisaged to participate in the presentations and discussions of the results of the present project where considered relevant. In preparation for this workshop, a handbook describing the project results as well as the methodologies and techniques used in the project will be published in three languages (English, French and Spanish) and be made available, at a price to be determined, to commercial and non-commercial operators. This publication is the property of the Fund.

Output 3.1 Providing information on project activities and results to other cotton-producing countries in Africa

Activity 3.1.1 Dissemination of information on project activities and results annually through the network of cotton-producing countries in Africa.

Activity 3.1.2 Dissemination of information on project activities and results annually through the network of cotton-producing countries through the Mediterranean network.

Output 3.2 Providing information on project activities and results to cotton-producing countries outside of Africa

Activity 3.2.1 Annual workshop on efforts to combat stickiness and its effects conducted as a part of the meeting of the Committee on Cotton Production Research of the International Cotton Advisory Committee, held at Plenary Meetings, and attended by researchers from member countries and observers.

Activity 3.2.2 Organization of a training/visitors programme for groups of selected staff of interested organizations.

Activity 3.2.3 Organization of an international workshop to disseminate the results of the project.

Output 3.3 Financial Analysis Report

Activity 3.3.1 Throughout the duration of the project, data will be collected related to present production, grading, pricing and marketing of cotton as well as with regard to the use and cost of the new methodology resulting in different qualities of cotton in as far as related to stickiness levels.

Activity 3.3.2 Based on the data gathered through Activity 3.3.1, an all inclusive financial and detailed analysis will be prepared by the PEA, possibly in cooperation with an international specialist in this field, on the viability in economic/financial terms of the stickiness detection process and the development and application of the after-ginning methods to enable processing of sticky cotton.

Output 3.4 Publication of a handbook for commercial utilization of project findings.

Activity 3.4.1 In preparation for the workshop in Activity 3.2.3, a handbook will be prepared in English regarding procedures necessary for the separation of sticky cotton from non-sticky cotton.

Activity 3.4.2 The handbook will be translated into French and Spanish languages and be made available to all member countries of the Fund and the ICAC. The handbook will also be made available to all cotton-producing countries and organizations through the ICAC secretariat. The price of the book will be determined by the Fund, in close consultation with the PEA and the ICAC.

D.1. Economic viability of qualitatively grading cotton bales for stickiness measured by H2SD

D.1.1. Current situation in Sudan

In Sudan, approximately 300,000 families cropped cotton on 280,000 hectares in the 1996/1997 season (Table D-1). Irrigated crops account for 90% of fiber production (approximately 100,000 tons annually). Two principal types of cotton are cropped:

- *Acala*: medium fiber, *G. hirsutum*;
- *Barakat*: extra long fiber, *G. barbadense*.

Acala englobes several cotton varieties, the principal being *Barac*. Other varieties are produced in low quantities: *Shambat* for long fiber, *Albar* and *Acraïn* for short fiber. Long and short fibers corresponded to only 1,790 tons in 1996/1997, i.e. less than 2% of total production.

The growing area, with fairly dispersed plots, is situated between 10° and 16° North, and 30° and 36° East. Cotton growing areas are divided into blocks covering an average of 4,000 ha. Average seed-cotton yield is nearly 1 ton/ha, i.e. 330 kg of fiber/ha. Two thirds of the seed-cotton produced is roller ginned (Table D-1). Ginning output corresponds to 34 to 35% for *Acala* and 32 to 33% for *Barakat*. The seed-cotton arrives at the ginning mills in 315 lbs bags. Bags containing highly sticky cotton, detectable with the naked eye, are removed. The others are sorted using a mainly visual grading system into 3 seed-cotton groups. Bags of the same grade are mixed regardless of their geographical origin and are ginned together. A mill containing 94 roller gins produces 1,000 bales / 24 hours, with each bale weighing 191 kg (420 lbs). Four bales out of every 100 in each batch are graded visually and manually, and a single bale is tested by HVI.

Table D-1: Statistics for Sudanese production in 1996/1997.

Area under cotton crops	280,000 ha
Total fiber production	100,000 tons (524,590 bales)
Production of Barakat fiber (extra long fiber)	23,860 tons (125,109 bales)
Production of Shambat fiber (long fiber)	666 tons (3,496 bales)
Production of Acala fiber (medium fiber)	74,406 tons (390,212 bales)
Production of Albar and Acraïn fiber (short fiber)	1,099 tons (5,773 bales)

The information given above can be used to estimate needs in terms of materials, laboratories, maintenance efforts, air conditioning, etc. It is noteworthy that these estimates are made on the basis of the hypothesis of a 'political' decision being made to grade the entire bale production for stickiness. At the end of the grading operation, the bales would then be grouped together into batches of "homogeneous" stickiness.

This paper attempts to evaluate the financial effect of this grading operation. It does not take account of the fact that Sudanese cotton has a reputation for being sticky since this image should improve thanks to the grading work which will thus have an impact on cotton sale price.

D.1.2. Estimating the cost of H2SD grading in Sudan

The cost of H2SD grading has been estimated in the United States to be US\$1.5 per bale (Watson, 1998). This estimation, based on grading using two H2SD measurements per bale, includes depreciation of the instruments, labor and the cost of the different consumables and spare parts. The approach envisaged by the author is doubtless inspired by HVI grading of production since this has become well established in the United States over the last few years.

D.1.3. H2SD grading conditions

The cost of H2SD grading may be different in Sudan primarily because of the difference in labor costs. A bale-by-bale grading of the entire Sudanese production may thus be evaluated under the following conditions:

- annual production: 500,000 bales (400,000 Acala and 100,000 Barakat);
- sampling: 2 samples per bale;
- number of measurements: 1 H2SD measurement per sample;
- standard cottons: 2 reference cottons for daily verification of the machines;
- grading duration: 26 weeks (from January 1 to June 30 each season);
- workload: 2 teams working 8 hours / day x 5 days a week;
- workforce: 2 technicians for each H2SD machine.

D.1.4. Number of H2SD machines

With the capacity to process 100 to 110 samples/hour, it is theoretically possible for one H2SD machine to analyze 800 samples in one 8-hour shift. However, in view of the time required to analyze the standard cottons, breaks taken by the workforce and the different handling operations required for the sample, it is reasonable to limit analysis rate to 600 samples, i.e. 300 bales per machine and per 8-hour shift.

The number of H2SD machines necessary to grade 500,000 bales in 26 weeks is thus:

$$= \frac{500000}{300 \times 2 \times 5 \times 26} = 6.4$$

i.e. 7 H2SD machines to grade 500,000 bales in 26 weeks.

D.1.5. Reference cottons (standard cottons)

A verification of each H2SD machine is necessary at the start of each shift, then every two hours, to guarantee constant readings. In the same manner as for HVI grading, two reference cottons (standards) of guaranteed stickiness (one slightly sticky and the other very sticky) need to be analyzed. Five verifications of the H2SD machines are therefore made using two standard cottons every 8 hours.

Three or four grams of cotton are necessary for each H2SD stickiness measurement. With two measurements per cotton, the total amount of standard cotton required is given by:

$$4 \times 2 \times 5 \times 2 = 80 \text{ g of each standard cotton per day.}$$

When considering the 26 weeks, this mass increases to 10.4 kg/cotton, i.e. a total of 20.8 kg for the two standard cottons.

D.1.6. Consumption of aluminum foil

For each stickiness count, the H2SD instrument consumes 30 cm of aluminum foil.

The total number of counts (bale samples + standard cottons) is given by:

$$500,000 \times 2 + 5,200 = 1,005,200 \text{ counts}$$

Consumption of aluminum foil is given by: $0.3 \times 1,005,200$, i.e. 302 km.

D.1.7. Workforce

With two operators per machine, the number of technicians in each 8-hour shift is 2×7 , i.e. a total of 28 technicians.

With one person in each team to manage and prepare the samples, the total number of technicians is 30 persons.

With two team managers and two engineers, management personnel can be restricted to 4 persons.

Workforce composition is therefore:

- 30 technicians,
- 2 team managers,
- 2 engineers.

Table D-2 presents our cost estimates for a single grading laboratory situated at Wad Medani close to Gézira (the most important production area in Sudan). This location would reduce the cost of sample collection and also provides pre-existing infrastructure in the form of an ARC laboratory (*Stickiness Testing Laboratory of ARC-Wad Medani*). Thus, if a different site is chosen, certain estimations would have to be modified, notably the cost of sampling (shipment and labor) and that of the different equipment already present in the ARC laboratory.

Table D-2: Estimated cost of H2SD grading, 2 counts/bale (500,000 bales).

Parameter	Unit price US \$	Cost US \$	Cost per bale US \$
7 H2SD machines (depreciation over 5 years)	90 000	126 000	0.252
Aluminum foil consumed: 302 km (Price in France, exclusive of VAT)	120	36 240	0.073
Maintenance and spare parts		30 000	0.06
1 air-conditioning system (depreciation over 10 years)	100 000	10 000	0.02
Energy consumed (130,000 kwh) (Source: SCC)	0,35	45 500	0.091
Workforce wages (6 months): 30 technicians	420	97 200	0.194

Parameter	Unit price	Cost	Cost per bale
	US \$	US \$	US \$
2 team managers	700		
2 engineers	1100		
Sampling (shipment, handling) (Source: SCC)		367 000	0.734
Data processing and communications (computer, tel., fax, etc.)		20 000	0.04
Standard cottons (21 kg)	200	4 200	0.008
Miscellaneous (approx. 2.7% of subtotal)		19 920	0.04
Total		756 060	1.51

The overall cost of grading 500,000 bales is thus estimated to be \$756,060, i.e. US\$1.51 per bale. This result is slightly higher than the estimation made in the United States (US\$1.25/bale). It should be noted that the American estimation does not detail the different costs and may not take account of the cost of collecting the samples and those relative to data processing. Here, the United States has already available a grading system (HVI) which includes the costs of the two supplementary operations we took into account in our estimation in Table D-2.

Even if the estimated cost exceeded \$1.5 per bale, the grading would still be cost-effective because of the discounting imposed on Sudanese cotton.

It is important to note that the true cost per sample for analysis purposes only (without sampling and transportation) is around **0.388 US\$ / sample**.

D.1.8. Cost-effectiveness of grading

H2SD grading becomes cost-effective if the difference between sales with and without grading is greater than or equal to its cost.

For production of n commercial types of cotton (or standard sales types), let P_i be the sales price of cotton i and NB_i be the number of bales of this cotton produced in the absence of any H2SD grading. Sales are:

$$CA = \sum_{i=1}^n P_i NB_i \quad (\text{Equation D-1})$$

After H2SD grading into two categories, sticky and non sticky, and with a hypothetical discount D_i (%) on the selling price of a non sticky proportion X_i of the NB_i bales, the revenue generated by the non sticky part of the production is given by:

$$\text{Selling price of the non sticky bales} = \sum P_i NB_i X_i / (1 - D_i) \quad (\text{Equation D-2})$$

where P_i is the actual price per bale of type i in the absence of grading.

Although grading can increase the price of the non sticky bales, it would probably contribute

to reducing the price of those graded as sticky. If the decrease is $D'_i\%$ in the price P_i , the revenue from the sticky part of the production is given by:

$$\text{Selling price of the sticky bales} = \sum P_i NB_i (1 - X_i) (1 - D'_i) \quad (\text{Equation D-3})$$

Sales after grading are therefore:

$$\begin{aligned} CA_{\text{Classification}} &= \sum_{i=1}^n \frac{P_i NB_i X_i}{1 - D_i} + \sum_{i=1}^n P_i NB_i (1 - X_i) (1 - D'_i) \\ &= \sum_{i=1}^n P_i NB_i \left[\frac{X_i}{1 - D_i} + (1 - X_i) (1 - D'_i) \right] \end{aligned} \quad (\text{Equation D-4})$$

If the cost of grading is CC , the gain at the end of this operation is:

$$\begin{aligned} \text{Gain} &= CA_{\text{Classification}} - CA - CC \\ &= \sum_{i=1}^n P_i NB_i \left[\frac{X_i}{1 - D_i} + (1 - X_i) (1 - D'_i) - 1 \right] - CC \end{aligned} \quad (\text{Equation D-5})$$

How does this gain vary as a function of the X_i proportions and the discounts D_i and D'_i ? Unfortunately, in view of the number of variables, it is impossible to devise a graphical response to this question. We therefore simplified the expression for a tabular presentation. To do this, we reasoned by type of cotton sold i since the number of bales per type sold is sufficiently high for us to calculate precisely the gain produced by grading.

The gain by type of cotton is given by:

$$\text{Gain}_i = P_i NB_i \left(\frac{X_i}{1 - D_i} + (1 - X_i) (1 - D'_i) - 1 \right) - NB_i CC_{\text{Bale}} \quad (\text{Equation D-6})$$

where CC_{Bale} is the cost of grading a bale.

D.2. Numerical application

The gain can be evaluated for total production of 500,000 bales made up of $n = 2$ types of cotton:

- | | | |
|----|------------------------------------|-------------------------|
| 1: | Acala (80% of total production), | $NB_1 = 400,000$ bales |
| 2: | Barakat (20% of total production), | $NB_2 = 100,000$ bales. |

The price of a bale can be set at the annual average listed in *Cotton Outlook* for 1998/99, i.e.: \$0.5714/lb for Acala and \$0.7574/lb for Barakat.

For 420 lbs bales, this gives:

$$P_1 = \$239.99/\text{ bale} \quad \text{and} \quad P_2 = \$318.11/\text{bale}$$

The revenue generated by the sale of 500,000 bales not graded by H2SD is:

$$\text{Sales} = (400,000 \times 239.99) + (100,000 \times 318.11) = \$127,807,000$$

On the basis of \$1.51/bale, (estimation given in Table D-2), we evaluated the gain provided by grading for different proportions of non sticky X and the depreciation of those graded as sticky D' , and this for several D currently imposed on all Sudanese production in the absence of grading.

Table D-3 and Table D-4 present the gains resulting from grading Acala and Barakat bales for different proportions X and depreciation D' if current discounting is considered to be $D = 7\%$.

Bale grading is not always gainful since this is highly dependent upon the proportion graded as non sticky and the discounting applied to the bales graded as sticky.

As an example, if the proportion of non sticky bales in Acala production is $X = 30\%$ and the discounting imposed in the absence of grading is $D = 7\%$, grading these Acala bales will lead to a loss even if the discounting of the 70% of bales graded as sticky is as low as $D' = 3\%$ (losses at $D' = 3\%$ amount to \$452,264).

Table D-3: The gain (millions of US\$) resulting from grading Acala bales into two categories, sticky and non sticky, for different proportions of non sticky bales X and discounting of the sticky bales D' . Discounting in the absence of grading $D = 7\%$ and grading cost $CC_{\text{Bale}} = \$1.51/\text{bale}$.

	D'								
X%	3	5	7	10	12	15	20	30	35
0	- 3.5	- 5.4	- 7.3	- 10.2	- 12.1	- 15.0	- 19.8	- 29.4	- 34.2
20	- 1.5	- 3.0	- 4.5	- 6.8	- 8.4	- 10.7	- 14.5	- 22.2	- 26.0
40	0.6	- 0.9	- 1.7	- 3.5	- 4.6	- 6.3	- 9.2	- 15.0	- 17.8
60	2.6	1.8	1.0	- 0.1	- 0.8	- 2.0	- 3.9	- 7.8	- 9.7
80	4.6	4.2	3.8	3.2	2.8	2.3	1.3	- 0.5	- 1.5
100	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6

Table D-4: The gain (millions of US\$) resulting from grading Barakat bales into two categories, sticky and non sticky, for different proportions of non sticky bales X and discounting of the sticky bales D' . Discounting in the absence of grading $D = 7\%$ and grading cost $CC_{\text{Bale}} = \$1.51/\text{bale}$.

	D'								
X%	3	5	7	10	12	15	20	30	35
0	- 1.1	- 1.7	- 2.4	- 3.3	- 3.9	- 4.9	- 6.5	- 9.7	- 11.3
20	- 0.4	- 0.9	- 1.5	- 2.2	- 2.7	- 3.5	- 4.7	- 7.3	- 8.6
40	0.2	- 0.1	- 0.5	- 1.1	- 1.5	- 2.1	- 3.0	- 5.0	- 5.8
60	0.9	0.6	0.4	0.0	- 0.2	- 0.6	- 1.2	- 2.5	- 3.2
80	1.6	1.4	1.3	1.1	1.0	0.8	0.5	- 0.1	- 0.4
100	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2

It is essential, for a more precise evaluation of grading cost-effectiveness, to establish not only the proportion of non sticky bales and the discounting imposed in the absence of grading, but also the depreciation expected for the bales graded as sticky.

The discount currently imposed on Sudanese cotton is deduced from market data and is estimated by SCC to be 7 to 12% of the selling price. Evaluating the expected depreciation of bales graded as sticky is more difficult. This depends on several factors, particularly economic effects, and should be evaluated on the basis of objective criteria that take account of the damage caused by sticky cotton.

D.3. Conclusion

The results obtained show clearly the feasibility of a qualitative stickiness grading system by H2SD (*High Speed Stickiness Detector*). The cost per sample is around 0.388 US\$ per sample to which should be added the sampling and transportation of samples to the laboratory. Once the stickiness of each bale has been determined, the producer can fix a stickiness threshold and thus guarantee that the stickiness of the bales he supplies is lower than the limits demanded by his clients. The effectiveness of such a grading procedure depends directly on the within-bale stickiness distribution. Thus, it is essential to evaluate this distribution locally since this could vary from one production zone to another.

It is also possible to adapt this procedure to H2SD grading into several stickiness categories. To do this, it would be sufficient to consider the upper limit of each stickiness grade as a critical threshold and proceed grade-by-grade in the same way as for grading into two categories, sticky and non sticky.

The cost-effectiveness of H2SD grading was estimated for different discounts applied to the selling price of bales graded as sticky and as a function of different proportions of non sticky bales and the discounting already imposed on cotton production with a reputation of being sticky.

The grading system would require several H2SD machines to process the entire production of the country. Between-machine repeatability should be evaluated to gain an appreciation of the precision of the results and their reproducibility. Studies concerning measurement repeatability are ongoing at CIRAD in partnership with several American and European laboratories.

A grading system into several stickiness categories can be envisaged (e.g. non sticky, sticky, very sticky). Here, it has been observed that the stickier the cotton, the more damage it causes. Because of this, the discount imposed on the price of sticky bales could be weighted for their degree of stickiness. This would oblige producers to grade the bales into several categories. The methodology is the same as that developed for grading into two categories, only batch management would be different, and above all more costly.

D.4. Dissemination of the findings

The following papers were published and presentations made in the course of the project. Other members of the project may have also done presentations of the data:

D.4.1. Publications

- Fonteneau Tamime O., Gozé E., Frydrych R., Dréan J.-Y. Qualitative Classification of Cotton Stickiness in H2SD High Speed Stickiness Detector. Accepted by Textile Research Journal.
- Fonteneau Tamime O., Frydrych R., Dréan J.-Y. Carded Spinning of sticky cotton. Part 1: Stickiness effects on productivity. Accepted by Textile Research Journal.
- Fonteneau Tamime O., Gurlot J.-P., Gozé E. Carded Spinning of sticky cotton. Part 2: Stickiness effects on quality. Accepted by Textile Research Journal.

D.4.2. Presentations

- Frydrych R., Tamime O., Gurlot J.-P., Gozé E., Le Blan T., Ahmed S. F., Abdin M. A., 2000, Sticky cotton effects on the carded spinning process, Cotton Beltwide Conferences, San Antonio (TX), USA, January 3rd to 10th, 2000.
- Chanselme J.-L., Fadlalla A.S., Goze E., Tamime O.F., Abdelatif A.H., 1998, Investigation of within-bale variability of stickiness measurement, World Cotton Conference 2, Athens (Greece), September 6th to 13th, 1998.
- Gozé E., Fonteneau Tamime O., Frydrych R., Gurlot J.-P., Dréan J.-Y., Niewiadomski J.-C., Lassus S., Goebel C. et Francalanci Ph., 1999, Avancement du Projet Soudan: Improve the Marketability of the Cotton Produced in the Zones Affected by Stickiness, Actes des Journées Coton du Cirad, Montpellier, July 19th to 23th, 1999, pp.259-262.

D.4.3. Posters

Tamime O., Gozé E., Frydrych R., Gurlot J.-P., 1999, Dréan J.-Y., 1999, Classement des balles de coton selon leur potentiel de collage mesuré par le High Speed Stickiness Detector (H2SD), Doctoriales de l'Université de Haute Alsace in Mulhouse (France), Mai 1999.

D.4.4. Seminars

- PhD presentation by Fonteneau Tamime O., June 26, 2000.
- Seminar ' Journée d 'information sur la mesure et la lutte contre le collage des fibres de coton ', June 26, 2000, Montpellier.
- Presentation of the results of the Project in Sudan, end of 2000: J.-P. Gurlot went to Sudan in December 2000 to present information collected during the project to 75 persons representing SCC, ARC, ginners, farmers. A report was presented, in 190 slides, the results available at that time. New information that was not presented is contained in this report which attempts to provide all the necessary scientific background to understand our conclusions.
- Final seminar in July 2001 in Lille.

D.4.5. Other information

Stickiness is a worldwide problem that has been the subject of considerable research. A non exhaustive list of the groups currently working on the topic is given below:

- International Textile Manufacturers Federation (ITMF):
 - Organization of a round test using stickiness measurement devices.
 - Probable recommendation of H2SD by this Committee.
- Comité Européen de Normalisation (CEN):
 - Working Group on standardization for SCT.
 - Working Group on standardization for H2SD.
 - Working Group on standardization for FCT/FQT.

Chapter E. Final conclusion

It would appear that stickiness is on the increase. Many authors in the bibliography give different reasons for this increase change e.g. changes in insecticides, possible resistance to insecticides, changes in processing machines etc. Many producing countries are affected by stickiness, and ICAC decided to sponsor a first project in 1993 to control insect-induced stickiness in the field. The project was known as « Sticky cotton: possible control methods from the plant to yarn ».

In parallel, some kind of stickiness evaluation was required to assess bale quality for commercial purposes. Thus, a new project, entitled « Improvement of the Marketability of the Cotton Produced in Zones Affected by Stickiness » was designed to address some of the basic questions and develop a method for characterizing stickiness.

This project, also sponsored by the International Cotton Advisory Committee, and funded by the Common Fund for Commodities, was carried out by ARC and SCC in Sudan, and by IFTH and Cirad in France with the support of ICAC.

The central objective of the project was to increase cotton producer revenues through the development of reliable methods to evaluate the stickiness of cotton bales, and determine (under factory conditions) the operational thresholds for the processing of contaminated sticky cotton.

A bale is declared as “sticky” if, during a processing step, e.g. spinning, its stickiness disrupts the spinning process, reduces spinning machines performances or decreases final product quality.

It should be noted here that classification requires a measuring tool, appropriate conditions for that tool, and good cotton production organization. All these conditions will impact on the success of such a classification system.

E.1. Qualitative classification of stickiness

In this part of the project, we investigated methods intended to manage the cotton and establish make a classification for its marketing.

As planned in the project, the SCT thermodetector, which was shown to be a good predictor of problems encountered during spinning and is the measuring device recommended by the International Textile Manufacturers Federation, was used to separate the sticky bales based on the number of sticky points. This method was shown to have its limits as a classification tool since it is slow and the results were biased by an operator effect. In the second part of the project, it was decided to use the H2SD instead of the SCT as it proved to be more reliable and faster.

The bales can be classified for stickiness in several manners, i.e.:

- a quantitative classification, namely each bale is labeled with a number of H2SD sticky points, and its associated confidence interval (tolerance);
- separation into two categories, “sticky” and “non sticky”, according to a determined threshold called the “crucial stickiness threshold”.

Both these methods require knowledge concerning the within-bale distribution of sticky points. The qualitative classification of the cotton bales was chosen to be more suitable for the situation.

From a specific experiment, it was shown that the sticky points were distributed in an aggregated manner: the number of sticky points in the tested bales followed a binomial negative statistical distribution whose shape factor and homogeneity was estimated for all the bales.

The aim of any classification is the guarantee a certain quality for a given bale. However, since fiber characteristics showed within-bale and within-lot variability, samples from one single bale or a single lot could show different results and this could result in complaints. This would be particularly awkward when producer results and purchaser results are different for the same bale

When classifying stickiness, at least qualitatively, this risk of complaints being made (i.e. risk of litigation) must be evaluated and sampling / classification conditions must be managed accordingly.

This is why tables were established on the basis of simulations that took account of:

- the statistical distribution observed
- producer requirements in terms of cotton production constraints
- the classification and grouping together of bales of homogeneous quality
- purchaser requirements
- and part of the economical cost of the operation.

Under these conditions, the classification method used by the producer must be based on a lower threshold than that employed by the purchaser, and thus reduce the risk of litigation.

The extent of stickiness was also evaluated within Sudan. Several thousand samples, produced by eight ginning plants located in different geographical zones were analyzed using the H2SD. The results showed that some zones are more affected by stickiness than others. It is therefore possible to consider developing a strategy for the follow-up and assessment of stickiness by concentrating the measurements on the zones where the classification is the most useful.

E.2. Stickiness measurement and relationship with technical hitches during spinning

Part of this study focused on the spin-ability of sticky cottons by processing several sticky cottons bales covering a wide range of stickiness. During the spinning of each of these bales, the breaks, stops and technical hitches were noted and used to calculate the output of each spinning machine.

Some cotton samples, taken from the opening of the bale up to the sliver, were used to monitor changes in cotton stickiness in the course of the processing. Different methods were used to measure the stickiness: SCT thermodetector, H2SD and HPLC chemical method. The sliver, roving-yarn and yarn quality were also monitored by analyzing samples taken at the different performed stages from cotton to yarn.

The spinning tests were performed in carded cycle for the two main types of spinning (ring and open-end spinning), under the temperature and relative humidity conditions usually recommended for processing in the absence of stickiness.

Some relationships were noted between the different stickiness levels and the production and quality criteria and were used to define the best indicator of stickiness, namely the number of sticky points measured by the H2SD fast detector.

This device, in addition to providing the result that correlated the most closely with the production criteria (breaks and output) and quality criteria (regularity, imperfections and properties of yarn strength) is the fastest and the most suitable for industrial application in the detection of stickiness in cotton bales.

The other measurements methods studied, i.e. SCT and sugar percentages measured by HPLC, were often correlated to the production and quality criteria, but the coefficients of determination (R^2) did not generally equal those obtained with the number of sticky points given by the H2SD. Moreover, the HPLC chemical measurement is unsuitable for an industrial application because it is costly and time-consuming.

The results of this study showed that the rowing frame was the most sensitive machine to stickiness. Considerable efficiency could be lost depending on the degree of stickiness because of breaks and the rolling-up of fibers around the rollers.

The open-end spinning seemed to be less sensitive to stickiness than the ring spinning. The loss of efficiency due to stickiness is gradual with a relatively gentle slope while the rate of breaks in the ring spinning process increased rapidly with stickiness potential.

Another noticeable difference between these two types of spinning processes concerned the yarn quality. Whereas the quality of ring spun yarn (coefficient of variation for mass, imperfections, tenacity) greatly depended on stickiness and deteriorated when stickiness increased, the properties of open-end yarn were only slightly sensitive to this problem.

It should be remembered that this experiment was conducted to determine a threshold to separate non-sticky and sticky bales. However, because of this gradual increase in the rate of incidents with stickiness, it was not possible to determine a single, overall threshold where spinning problems become too important.

In fact, the threshold depends on the number of incidents accepted by the customer. Also the rate of incidents remains rather variable from one bale to another for a same number of H2SD sticky points.

In view of the extensive work that would be necessary to list the incidents for every bale, the small number of bales could be used to establish only a rather imprecise relationship between the acceptable rate of breaks and the stickiness threshold.

Some tests on combed spinning were conducted in order to study the relationships between stickiness and disruptions of the specific machines used in this type of spinning process: the combing machine and the lap top machine. However, as the range of stickiness was rather limited, the study was conducted in a set of bales that all showed low stickiness potential.

Nevertheless, the few tests conducted showed that the combing machines we used in the project seemed to be very sensitive to stickiness, inducing a relatively large number of registered breaks. This proves that stickiness may be damaging for production in modern spinning mills.

E.3. Financial viability of a classification

The cost of grading all bales produced in Sudan was assessed along with the actual financial gains from such an operation, taking into account the discounts applied to cottons with the reputation of being sticky and the proportion of bales in the whole production. The results of this economic assessment showed the cost of grading to be about 1.5 \$US per bale (almost 50% of this price for sample shipment to the testing laboratory since sample collection is not yet centralized) for an analysis cost of 0.388 \$US per sample. A grading system is only economically viable if it results in some financial gain and this depends on the discount

applied and the proportion of non-sticky bales. This study was conducted on the basis of many assumptions that need to be checked since it was almost impossible to obtain price and discount information from the market.

E.4. Solutions to reduce the consequences of stickiness

It is recognized that the higher the relative humidity, the most numerous the disruptions induced by cotton stickiness and the poorer the quality of the yarn. This negative effect was confirmed by reducing the relative humidity to 40% in a specific spinning experiment.

Three levels of relative humidity (40, 45, 55%) were tested to evaluate impact on productivity and the yarn quality in micro-spinning. Some tests conducted in an industrial spinning confirmed that very sticky bales which could be spun or were very difficult to spin under normal relative humidity (RH) conditions were spin-able without much disruptions at 38% RH. The quality of the yarns produced was also improved. Decreasing the relative humidity would appear to be a solution for the processing of sticky cottons.

In the scope of this study where each bale of cotton was spun individually, it was shown that the number of disruptions was related to the H2SD stickiness level. In industrial processing, cottons from different origins are often mixed together.

The linearity of H2SD counts in mixtures of sticky and non-sticky cottons was checked in samples containing 25, 50, 75 and 100% sticky cotton.

The stickiness of the mix was determined to be the mean stickiness of each constituent weighted by the proportion of this constituent in the mix (if the sticky cotton contains no more than 50 H2SD sticky points)..

Though there is no doubt that this observation needs to be confirmed in an extensive industrial spinning process and with respect to the quality of the yarn produced, it seems reasonable to imagine that mixing some sticky with some non sticky cotton could reduce the incidence of technical problems in the mill to an acceptable level.

E.5. Perspectives

Controlling stickiness requires a global approach where improvements in breeding, agronomy, pest control and technology have to be made in a parallel manner. Classification is one of the tools used to combat stickiness. Measurement results can help, through mapping, to make progress in all other ways to reduce stickiness, such as breeding new varieties, developing new ways to manage the crops through integrated pest management programs, managing the seed-cotton flow, etc.

On a long term basis, the classification tool should be economically viable, and would insure an improvement of the image of Sudanese cotton.

Chapter F. Review of the experimental approaches

F.1. General

1. The stickiness indicators were chosen on the basis of existing methods available on the market at different key points in the course of the project.
 - First, the SCT was chosen as the stickiness indicator since it is recognized by the textile representative body: the ITMF.
 - Then, an HPLC method to measure stickiness was added to lend further support to the measurement since this method is able to measure the different honeydew constituents.
 - And finally, H2SD was used during the last years of the project.
2. This induced changes in the planning of the activities in comparison to the initial planning. Many experiments were duplicated in order to ensure follow-up and comparisons between the results.
3. Other stickiness measuring techniques that did not exist in the first years of the project, are now available on the market. These techniques were not tested in this project, since this could have obliged us to duplicate experiments that had already been duplicated.
4. It is important to note that:
 - SCT was invented and improved between 1986 and 1994, the latter being to date on which it was recommended by ITMF. Subsequent changes corresponded to ‘fine tuning’ through standardization procedures to improve between-machine and between- laboratory reproducibility. In view of this, it was decided to use SCT for the complete duration of the project
 - H2SD was created in 1992 and was under development up to 1996, date of the beginning of this project. However, as with all new techniques, H2SD was improved during the project on the basis of the observations we made when testing Sudanese samples. In the meantime, a strong effort was initiated by many working groups and teams in the world to ‘standardize’ many technical terms, techniques and recommendations concerning the stickiness problem. In these conditions, work using the H2SD, and some other measuring techniques more or less depended on the results obtained worldwide and progress made, and was also contributing to this progress. The H2SD results in the course of this project were obtained using state-of-the-art technology at the time the test was performed.
5. HPLC results showed that both physiological and entomological sugars were present in the cotton bales processed and that total sugar content was relatively high. We were not able to separate physiological sugars from entomological sugars in terms of their effect on the spinning process. Thus, a fiber maturity problem could lead to stickiness effects, enhanced by insect infestation which was high during the sampled crop. Usually, HPLC results can distinguish between sugars from Aphids and those from White-flies, but this was not the case for this experiment. On the other hand, Khalifa stated that white-flies are the main insect in the Sudanese fields. As these two observations do not match, it may be assumed that both insects were present in the bales because both melezitose and trehalulose were present. More experiments are therefore required to discover more about the type of honeydew produced by the various insects (the size of honeydew droplets are different) and their effect on spinning.

F.2. Component A

The complexity of the modeling and the attempts made to fit the data to a complex statistical distribution.

- Even though a huge amount of work was undertaken to standardize the stickiness measurements in the course of the project, no reference cottons with known levels of stickiness existed to periodically check the stickiness readings over a long time period. For future projects, as soon as reference cottons are produced, it will be necessary to check the long term stability of the measurements.
- Evaluating the variability of stickiness at different levels (bales, lots...) is a difficult and long term task.

F.3. Component B

A choice was made to conduct the spinning tests on complete bales at a given stickiness level in order to highlight problems in both productivity and quality. Thus, bales with a wide range of stickiness levels were used during the tests.

Each bale only required a few hours of processing in the first steps (blowing room up to the drawing frame), while it took some days to process to the latest steps (flyer to ring spinning, and open-end spinning). Thus, even though these experiments provided interesting information concerning the effects of stickiness, the results and conclusions are of limit use.

Remarks can be made on this way the experiments were conducted:

- Spinners generally do not process individual bales, especially when there are likely to cause problems. They usually prefer to process batches that could take days.. As far as we know, spinners generally try to avoid stickiness by different means such as i) avoiding the purchase of ‘sticky’ areas, ii) diluting cotton ‘sticky’ bales through mixes with ‘free’ or ‘low’ stickiness level bales, iii) decreasing relative humidity in the workshops, iv) increasing manpower to clean, maintain yarn production, v) combination of two or more of these solutions, etc. This solution could not be used in this project for research purposes since a wide range of stickiness level had to be used to understand the consequences of stickiness in the spinning mills.
- Processing bale per bale does not highlight long-term contamination problems on spinning machines. Indeed, at least for the first processing steps, the machine running time was relatively short, and stickiness had no time to accumulate on the critical parts of the machines. The same restriction introduces relatively low precision into the determination of productivity parameters.
- No spinning test were conducted during the experiment on a binary mix of a non-sticky and sticky cottons with different stickiness levels in different proportions. The conclusion here was that the stickiness level of a mix can be determined from the stickiness level of the constituents in the mix and their proportion in the mix. This assumes that all sticky points have the same effect on productivity and quality parameters. This result should be checked through full scale experiment, since we suspect that the size of the sticky points may affect the type of disorder induced (in this project, no significant relation was proven between the size of the sticky point and any quality or productivity parameter). Results from this validation experiment may result in changes in H2SD settings to render its results more precise.
- During the micro-spinning experiment on the effect of relative humidity, low quantities of cotton were processed to yarn and the time required to do so was low. In consequence, the

precision of productivity parameters was low, but are a good idea of what could appear in a full-scale spinning mill. It is important to note that the mini-card machine, which is one of the components of the micro-spinning equipment, is still the ITMF reference method for stickiness measurement.

F.4. Component C

- As usual, the economic study can easily be criticized because of the lack of price information from the market place. More precision in the analysis can be achieved if more information is collected.
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- All calculations were made in reference to a given statistical distribution, that may change depending on the type of crop management system used.

The classification cost (1.51 \$US / bale or 0.388 \$US / sample without shipment) takes account of all known costs for a classification process including cost of collecting the samples and shipping them to a central laboratory that accounts for almost 50% of the global cost. If a global classification is designed in Sudan for HVI and stickiness classification, this shipment will be reduced.

Chapter G. References

- AFNOR, 1980. Textiles fibres et fils. Recueil de normes françaises, 465 p.
- ALI N.A., KHALIFA H., 1980. Development of methods to measure cotton stickiness. *Coton et Fibres Tropicales*, 35, 4, 411-413.
- ANONYME, 1992. Sweet cotton sticky. *Textile Asia*, October, 117-118.
- ANTHONY W.S., and BYLER R. K., 1999. Rapid estimation of cotton stickiness, *Proceeding Beltwide Cotton Conference*, Orlando, FL, USA, 690-692.
- ARTZ P. and SCHMIDT H. P., 1998. A robust practical method for evaluating the quality of raw material, including stickiness. *International Cotton Conference*, Brème, Allemagne, 63-72.
- BAILEY N. M., BAILEY C. A., REICHARD S. M., 1982. Enzymatic evaluation of sugar content of cotton. *Textile Research Journal*, 52, 321-327.
- BALDWIN J.C., QUAUD M., SCHLETH A.C., 1995. Afis seed coat nep measurement. *Proceedings, Beltwide Cotton Conference*, San Antonio, Texas, Etats-Unis, 2, 1250-1253.
- BALASURBRAMANYA R. H., BHATAWDEKAR S. P., PARALIKAR K. M., 1985. A new method for reducing the stickiness of cotton. *Textile Research Institute*, April, 227-231.
- BAR-YECHESKEL H., WEINBERG A., STERNHEIM A., 1994. Improved assessment of the honeydew content in cotton through the utilisation of Shenkar Stickiness Test. *Proceedings, International Committee on Cotton Testings Methods of ITMF*, Brème, Allemagne, appendix 27, 1-14.
- BECKHMAN C. M., 1969. Effect of nitrogen fertilization on the abundance of cotton insects. *Journal of Economic Entomology*, 63, 4, 1219-1220.
- BOURELY J., 1980. Contribution à l'étude des sucres du cotonnier. *Coton et Fibres Tropicales*, 35, 2, 189-208.
- BOURELY J., GUTKNECHT J., FOURNIER J., 1984. Etude chimique du collage des fibres de coton. Première partie. *Coton et Fibres Tropicales*, 39, 3, 47, 47-53.
- BOURELY J., HAU B., 1991. Le cotonnier sans gossypol. *Coton et Fibres Tropicales*, série Documents, Etudes et Synthèses n° 12, 70 p.
- BRUSHWOOD D.E., PERKINS H., H., Jr., 1993. Cotton stickiness potential as determined by minicard, thermodetector and chemical methods. *Proceedings, Beltwide Cotton Conference*, New Orleans, Louisiane, Etats-Unis, 3, 1132-1135.
- BRUSHWOOD D.E., PERKINS H., H., Jr., 1994. Characterization of sugars from honeydew contaminated and normal cottons. *Proceedings, Beltwide Cotton Conference*, San Diego, Californie, Etats-Unis, 3, 1408-1409.
- BUTLER G.D., LOPER G.M., GREGOR M., WEBSTER, MARGOLIS, 1972. Amounts and kinds of sugars in the nectars of cotton and the time of the secretion. *Agronomy Journal*, 64, 364-368.
- BUTLER G.D., JR., RIMON D., HENNEBERRY T.J., 1988. *Bemisia tabaci* (Homoptera Aleyrodidae): populations on different cotton varieties and cotton stickiness in Israel. *Crop Protection*, 7, 43-47.
- BUTLER G.D., Jr., HENNEBERRY T.J., 1994. *Bemisia* and *Trialeurodes* (Hemiptera: Aleyrodidae). *Cab International, Insects pests of cotton*, édité par MATTHEWS G.A. et TUNSTAL J.P., 325-352.
- CARTER F., 1990. The problem of sticky cottons in the USA and strategies for control. In: *Cotton production research from a farming perspective, with special emphasis on stickiness*. Paper presented at a Technical Seminar at the 49th Plenary meeting of the ICAC, Montpellier, France, 37-41.
- CAUQUIL J., VAISSAYRE M., 1971. La "maladie bleue" du cotonnier en Afrique: transmission de cotonnier à cotonnier par *Aphis gossypii* Glover. *Coton et Fibres Tropicales*, 26, 463-466.
- CAUQUIL J., VINCENS, 1982. Maladies et ravageurs du cotonnier en Centrafrique. Expression des dégâts et moyens de lutte. *Coton et Fibres Tropicales*, série Documents, Etudes et Synthèses n° 12, 70 p.1, 32 p.
- CAUQUIL J., VINCENS P., DENECHERE M., MIANZE TH., 1982. Nouvelle contribution sur la lutte chimique contre *Aphis gossypii* Glover, ravageur du cotonnier en Centrafrique. *Coton et Fibres Tropicales*, 37, 4, 333-350.
- CAUQUIL J., FOLLIN J.C., 1983. Les maladies du cotonnier attribuées à des virus ou des mycoplasmes en

Afrique du sud du Sahara et dans le reste du monde. Coton et Fibres Tropicales, 36, 4, 293-308.

CAUQUIL J., GIRARDOT B., VINCENS P., 1986. Le parasitisme des cultures cotonnières en République centrafricaine : définitions des moyens de lutte. Coton et Fibres Tropicales, 41, 1, 5-19.

CAUQUIL J., VAISSAYRE M., 1994. Protection phytosanitaire du cotonnier en Afrique tropicale. Agriculture et Développement, 3, 13-23.

CHANSELME J. L., HEQUET E., and FRYDRYCH R., 1997. Relationship between AFIS fiber characteristics and yarn evenness and imperfections. Beltwide Cotton Conferences, January 6-10, New Orleans, La (USA), National Cotton Council, Memphis, Tn (USA), pp. 512-516.

CHANSELME J.-L., FADLALLA A.S., GOZE E., TAMIME O.F., ABDELATIF A.H., 1998, Investigation of within-bale variability of stickiness measurement, World Cotton Conference 2, Athens (Greece), September 6th to 13th, 1998.

CHIOU H. H. and LEE S. H., 1994. Methods for testing sticky cotton. Proceeding, 53rd Plenary meeting of ICAC, 59-51.

CRESSIE N., "Statistics for Spatial Data", John Wiley, NY, 1991.

COUILLOUD R., 1986. Quelques données bibliographiques sur les insectes producteurs de miellat. Coton et Fibres Tropicales, 41, 3, 225-228.

DAGNELIE P., 1975. Théorie et méthodes statistiques. Les Presses agronomiques de Gembloux, ASBL., vol. 1, 450 p. et vol. 2, 463 p.

CHUN D. T. W. and BRUSWOOD D., 1998. High moisture storage effects on cotton stickiness. Textile Research Journal, 68(9), 642-648.

DEGUINE J.P., GOZE E., LECLANT F., 1994. Incidence of early outbreaks of the aphid *Aphis gossypii* Glover in cotton growing in Cameroon. International Journal Pest Management, 40, 2, 132-140.

DEGUINE J.P., 1995. Etude bioécologique et épidémiologique du puceron *Apis gossypii* Glover, 1877 (Hemiptéra, Aphididae) sur cotonnier en Afrique Centrale. Vers une évolution de la protection phytosanitaire. Ecole nationale supérieure agronomique de Montpellier, France, Thèse, 168 p.

DEGUINE J.P., LECLANT F., 1996. *Aphis gossypii* Glover, 1877. Les déprédateurs du Cotonnier en Afrique Tropicale et dans le reste du monde (à paraître en 1996).

DELATTRE R., 1973. Parasites et maladies en culture cotonnière. Manuel phytosanitaire CIRAD, 146p.

DEMUTH R. R., 1992. Industrial online removal of stickiness. Textil Praxis International (Foreign Edition), 4, 297-299.

DENHOLM I., BIRNIE L. C., 1990. Prospects for managing resistance to insecticides in the whitefly. In : Cotton production research from a farming perspective, with special emphasis on stickiness. Papers presented at a Technical Seminar at the 49th Plenary meeting of the ICAC, Montpellier, France, 37-41.

DITTRICH V., ERNST D.H., RUESCH O., UK S., 1990. Resistance mechanisms in sweetpotato whitefly (homoptera : Aleyrodidae) populations from Sudan, Turkey, Guatemala and Nicaragua. Journal of Economic Entomology, 83, 5, 1665-1670.

DREAN J.-Y., KRIFA M., GOURLLOT J.-P., 1998. Débris de coques en filature. L'industrie Textile, n°1295, 33-35.

EKUKOLE G., 1992. Effect of some agronomic and chemical control practices on *Aphis gossypii* populations and stickiness in cotton. Coton et Fibres Tropicales, 47, 2, 139-143.

EKUKOLE G., 1992. Preliminary results on the effect of pruning cotton plants on *Aphis gossypii* Glover populations in Maroua, north Cameroon. Coton et Fibres Tropicales, 47, 2, 135-138.

EL MOGAHZY Y.E., BROUGHTON R., and LYNCH W. K., 1990. Statistical approach to determining the technological value of cotton using High Volume Instrument fiber properties. Textile Research Journal, 60 (9): 495-500.

ELSNER O., 1982. A quick and simple method for sugars and honeydew detection on cotton lint. Proceedings, International Committee on Cotton Testing methods, ITMF, Brème, Allemagne, 2 p.

- ELSNER O., HANI J., LUBENEVSKAYA E., 1983. The sugar content in cotton lint of growing bolls. *Coton et Fibres Tropicales*, 38, 2, 223-227.
- ETHRIDGE D. and ZHU R., 1997. Predicting yarn quality using measurements at alternative stages of the spinning process. Beltwide Cotton Conferences, January 6-10, New Orleans, LA, USA, National Cotton Council of America. Memphis, TN (USA), pp. 696-705.
- ETHRIDGE D. and HEQUET E. F., 1999. Status of high volume instrument measurements of stickiness in cotton, Proceedings, Beltwide Cotton Conference, Orlando, FL, USA, 701-704.
- FISHER, R. A., "Statistical Methods for Research Workers", 7th ed., Oliver and Boyd, Edinburgh, U. K., 1938.
- FLOECK H. and ETHRIDGE D., 1998. How textile manufacturers dealt with sticky cotton from the 1995 crop, Proceedings, Beltwide Cotton Conference, San Diego, CA, USA, 284-287.
- FONTENEAU TAMIME O., FRYDRYCH R., GOURLOT J.-P., DREAN J.-Y., GOZÉ E., 2000, Filature cardée des cotons collants :Effet du collage sur la productivité et la qualité des filés, lors de la Journée d'information sur la mesure et la lutte contre le collage des fibres de coton, 26 juin 2000, Montpellier, France.
- FONTENEAU TAMIME O., FRYDRYCH R., DREAN J.-Y. Carded Spinning of sticky cotton. Part 1: Stickiness effects on productivity. Accepted by Textile Research Journal.
- FONTENEAU TAMIME O., GOURLOT J.-P., GOZE E. Carded Spinning of sticky cotton. Part 2: Stickiness effects on quality. Accepted by Textile Research Journal.
- FONTENEAU TAMIME O., GOZE E., FRYDRYCH R., DREAN J.-Y. Qualitative Classification of Cotton Stickiness in H2SD High Speed Stickiness Detector. Accepted by Textile Research Journal.
- FOURNIER J., GUTKNECHT J., JALLAS E., BOURELY J., 1985. Etude chimique du collage des fibres de coton, 2^o partie. *Coton et Fibres Tropicales*, 42, 2, 113-132.
- FRYDRYCH R., 1986 - Détermination du potentiel de collage des cotons par thermodétection. *Coton et Fibres Tropicales*, 41, 3, 211-214.
- FRYDRYCH R., 1987 - Une nouvelle méthode pour la détermination du potentiel de collage des cotons. Université des sciences et techniques du Languedoc, Montpellier, France, DES, 62 p.
- FRYDRYCH R., GUTKNECHT J., 1989. Identification et comptage des diverses imperfections rencontrées sur le fil de coton. *Coton et Fibres Tropicales*, 44, 1, 59-65.
- FRYDRYCH R., 1991. Etude sur les cotons collants. Effet des cotons collants sur les imperfections du fil. Document interne CIRAD, journées des sélectionneurs et des technologistes, Montpellier, France, 12 p.
- FRYDRYCH R., 1991. Evaluation de la résistance du fil à partir des caractéristiques technologiques de la fibre. *Coton et Fibres Tropicales*, 46, 3, 243-247.
- FRYDRYCH R., 1991. Brevet pour : procédé de traitement en ambiance humide du coton et installation pour la mise en oeuvre du procédé, PCT/FR92/01230 du 23/12/92.
- FRYDRYCH R., 1991. Brevet pour : procédé de traitement du coton par injection de vapeur d'eau chaude et installation pour la mise en oeuvre du procédé, PCT/FR92/01231 du 23/12/92.
- FRYDRYCH R., 1992. Brevet pour : procédé et installation pour l'évaluation du caractère collant de matières fibreuses végétales telles que des cotons et utilisation de ce procédé et de cette installation, PCT/FR93/00457 du 11 mai 1993.
- FRYDRYCH R., HEQUET E., GOZE E., 1992. Comparaison IRCT-RF13 et GRAF SCT avec 2 modalités d'ouverture des cotons. Document interne CIRAD, 18 p.
- FRYDRYCH R., 1993. Le thermodétecteur SCT. Manuel technique CIRAD, 15 p.
- FRYDRYCH R., 1993. L'enceinte à conditionner FG 49. Manuel technique CIRAD, 8 p.
- FRYDRYCH R., GOURLOT J.P., 1993. Evaluation de la résistance du fil à partir des caractéristiques technologiques de la fibre obtenues sur HVI. *Coton et Fibres Tropicales*, 48, 3, 201-206.
- FRYDRYCH R., GOZE E., HEQUET E., 1993. Effet de l'humidité relative sur les résultats obtenus au thermodétecteur. *Coton et Fibres Tropicales*, 48, 4, 305-311.

- FRYDRYCH R., HEQUET E., VIALLE M., 1993. Incidence du stockage sur l'évolution du potentiel de collage des cotons. *Coton et Fibres Tropicales*, 48, 3, 207-212.
- FRYDRYCH R., FRYDRYCH D., 1993. Les cotons collants : un problème mondial. *L'Industrie Textile*. n. 1239, p.27-29.
- FRYDRYCH R., 1993 - Manuel technique des appareils commercialisés : le thermodétecteur SCT; l'enceinte à conditionner FG 49.
- FRYDRYCH R., HEQUET E., CORNUEJOLS G., 1994. A high speed instrument for stickiness measurement. 22 th International Cotton Conference of ITMF, Brème, Allemagne, 83- 91.
- FRYDRYCH R., HEQUET E., BRUNISSEN C., 1995. High speed stickiness detector : relation with the spinning process. *Proceedings, Beltwide Cotton Conference, San Antonio, Texas, Etats-Unis*, 2, 1185-1189.
- FRYDRYCH R., 1996 - Contribution à l'étude du collage des cotons au moyen de méthodes mécaniques et thermomécaniques. Université de Haute Alsace, Mulhouse, France, thèse de doctorat, 199 pages.
- FRYDRYCH R., HEQUET E., 1996. Standardisation proposals : the thermodetector and its methodology. *Proceedings, International Committee on Cotton Testing Methods of ITMF, Brème, Allemagne*, sous presse.
- FRYDRYCH R., 1998. The commercial H2SD – a status report. *Proceedings of the meeting of the International Committee on Cotton Testing, Bremen, International Textile Manufacturers Federation, Zürich*, 103-106.
- FRYDRYCH R., KRIFA M., TAMIME O., GINER M., GOURLOT J.-P., 1999, Detection and counting of two cotton contaminants : Seed coat fragments and honeydew deposits, *Cotton Beltwide Conferences, Orlando (FL), USA du 3 au 10 janvier 1999*, pp. 695-698.
- FRYDRYCH R., TAMIME O., GOURLOT J.-P., GOZE E., LE BLAN T., AHMED S. F., ABDIN M. A, 2000, Sticky cotton effects on the carded spinning process, *Cotton Beltwide Conferences, San Antonio (TX), USA du 3 au 10 janvier 2000*.
- FRYDRYCH R., GAWRYSIAK G., GOURLOT J.-P., 1999, What is stickiness ? What are its consequences ?, Réunion CEN TC248 à Porto.
- FRYDRYCH R., GAWRYSIAK G., GOURLOT J.-P., 1999, STANDARDIZATION PROPOSALS : The thermodetector and its methodology, Réunion CEN TC248 à Porto.
- FRYDRYCH R., GAWRYSIAK G., GOURLOT J.-P., 1999, STANDARDIZATION PROPOSALS : The H2SD, methodology and results, Réunion CEN TC248 à Porto.
- FRYDRYCH R., GOURLOT J.-P., 2000, Présentation du High Speed Stickiness Detector (H2SD) et des résultats obtenus , lors de la Journée d'information sur la mesure et la lutte contre le collage des fibres de coton, 26 juin 2000, Montpellier, France.
- FRYDRYCH R. and DREAN J.-Y. (2000), "A new methodology usable by researchers and spinners for short staple fiber micro-spinning", *Beltwide Cotton Conferences, January 4-8, San Antonio, TX (USA), National Cotton Council of America. Memphis, TN (USA)*, pp. 1555-1556.
- GACON F., 1989. Réalisation pratique des mesures du collage de la fibre par thermodétection; premiers résultats en Afrique francophone. *Actes de la 1re conférence de la recherche cotonnière africaine, Lomé, Togo*, 1, 211-214.
- GHOVANLOU H., 1974. Etude de divers aspects morphologiques et de leur déterminisme chez *Aphis gossypii* Glover. *Etude morphologique. Coton et Fibres Tropicales*, 29, 345-352.
- GINER M., GOURLOT J.-P., BACHELIER B., AHRONOWITZ E., HUGON M., DAMIAND G., 1997, Latest Developments and results in automatic SCF counting. Part I: development of algorithms and preliminary results, *Beltwide Conference New Orleans, USA, 6-10/01/97*.1633-1637.
- GOSH S., ROY R. B., 1988. Quantitative near-infra-red analysis of reducing sugar from the surface of cotton. *Journal Textile Institute*, 3, 504-510.
- GOUET J.P., PHILIPPEAU G., 1989. Comment interpréter les résultats d'une analyse de variance. *STAT-ITCF, Institut Technique des Céréales et des Fourrages*, 47 p.
- GOURLOT J.P., 1992. High Volume Instrument : les résultats et les conséquences. Document interne CIRAD, journées des sélectionneurs et des technologistes, Montpellier, France, 13 p.

GOURLOT J.P., FRYDRYCH R., HEQUET E., THOLLARD F., CONSTANTIN O., BACHELIER B., 1995. Seed coat fragment counting and sizing in card web. Proceedings, Beltwide Cotton Conference, San Antonio, Texas, Etats-Unis, 2, 1245-1249.

GOURLOT J.-P., GINER M., HEQUET E., AHRONOWITZ E., HUGON M., DAMIAND G., 1997, Latest Developments and results in automatic SCF counting. Part II: Improved image acquisition and results obtained, Beltwide Conference New Orleans, USA, 6-10/01/97, Proceeding du Beltwide San Diego 5-9/01/98 pp. 1522-1524.

GOURLOT J.-P., FRYDRYCH R., GAWRYSIAK G., 1998, New cotton fiber measurements : Advantages for the spinner, Conférence du 20^e anniversaire du Kasetsart University Research and Development Institute, Bangkok du 28 sept. au 4 octobre 98.

GOURLOT J.-P., 1998, Recent evolution in the international standardization, réunion du Réseau Coton Méditerranéen, du 14 au 19 juillet 1998, Montpellier France.*

GOURLOT J.-P., KRIFA M., FRYDRYCH R., CHANSELME J.-L., 1998. Honeydew and seed coat fragments : identifying and counting two major cotton fiber contaminants. World Cotton Research, Conference 2 : " New frontiers in cotton research ", September 6-12, 1998. Athens, Greece.

GOURLOT J.-P., 2000, Résumé et conclusions de cette journée : Le collage de la plante au fil : les moyens de lutte, lors de la Journée d'information sur la mesure et la lutte contre le collage des fibres de coton, 26 juin 2000, Montpellier, France.

GOURLOT J.-P., 2000, Remerciements, lors de la Journée d'information sur la mesure et la lutte contre le collage des fibres de coton, 26 juin 2000, Montpellier, France.

GOURLOT J.-P., FRYDRYCH R., 2000, High Speed Stickiness Detector, Présentation à Bremen, International Textile Manufacturers Federation, Working Group 'Stickiness', February 28 & 29, 2000.

GOURLOT J.-P., 2000, Présentation du projet Soudan, lors de la Journée d'information sur la mesure et la lutte contre le collage des fibres de coton, 26 juin 2000, Montpellier, France.

GOURLOT J.-P., GOZÉ E., FRYDRYCH R., 2000, Choix du type de classement et du matériel utilisé, lors de la Journée d'information sur la mesure et la lutte contre le collage des fibres de coton, 26 juin 2000, Montpellier, France.

GOURLOT J.-P., FRYDRYCH R., FONTENEAU-TAMIME O., BACHELIER B., GOZE E., 2000, Improve the marketability of the cotton produced in the zones affected by stickiness, tous les résultats du projet Soudan, Wad Medani, Soudan, 07/12/2000.

GOURLOT J.-P. *et Al*, 2000, Effet de la variabilité des critères de qualité des fibres de coton sur leur aptitude à la filature et la qualité des fils produits, Actes des Journées Coton du Cirad, Montpellier, du 17 au 21 juillet 2000, pp. 305-319.

GOZE E., 1990. Research on the causes of sticky cotton in a farming system in tropical africa. In: Cotton production research from a farming perspective, with special emphasis on stickiness. Paper presented at a Technical Seminar at the 49th Plenary meeting of the ICAC, Montpellier, France, 19-24.

GOZE E., 1993. Appui méthodologique aux chercheurs du projet Garoua II. Document interne CIRAD, 63 pages.

GOZE E., 1998. Etude de la variabilité intra-balle du collage sur 1000 balles du Soudan. Rapport du Cirad, Montpellier, 14 pages.

GOZE E., FONTENEAU TAMIME O., FRYDRYCH R., GOURLOT J.-P., DREAN J.-Y., NIEWEADOMSKI J.-C., LASSUS S., GOEBEL C. et FRANCALANCI Ph., 1999, Avancement du Projet Soudan : Improve the Marketability of the Cotton Produced in the Zones Affected by Stickiness, Actes des Journées Coton du Cirad, Montpellier, July 19th to 23th, 1999, pp.259-262.

GOZÉ E., FRYDRYCH R., GOURLOT J.-P., FONTENEAU TAMIME O., 2000, Variabilité du collage et faisabilité d'une classification commerciale avec le H2SD, lors de la Journée d'information sur la mesure et la lutte contre le collage des fibres de coton, 26 juin 2000, Montpellier, France.

GROVER E. B., HAMBY D. S., 1960. Humidity and moisture. Handbook of textile testing and quality control, édité par Interscience publishers, Inc, 141-154

GUTKNECHT J., 1982-a. Le séchage du coton graine. Document interne CIRAD, 13 p.

- GUTKNECHT J., 1984. Prédiction de la résistance du fil. *Coton et Fibres Tropicales*, 39, 2, 25-29.
- GUTKNECHT J., FOURNIER J., FRYDRYCH R., 1986. Influence de la teneur en eau et de la température de l'air sur les tests de collage des cotons à la minicarde de laboratoire. *Coton et Fibres Tropicales*, 41, 3, 179-190.
- GUTKNECHT J., FOURNIER J., FRYDRYCH R., 1988. Principales recherches effectuées par l'IRCT sur l'origine et la détection des cotons collants. *Coton et Fibres Tropicales*, série Documents, Etudes et Synthèses n° 9, 42 p.
- GUTKNECHT J., FRYDRYCH R., 1988. L'enceinte à conditionner FG49 pour humidifier le coton avant le test de collage au thermodétecteur. *Coton et Fibres Tropicales*, 43, 2, 147-152.
- HECTOR D., HODKINSON I.D., 1989. Stickiness in cotton. *ICAC Review*, Articles on Cotton Production Research n° 2, 43 p.
- HENDRIX R. L., WEI Y-A., LEGGETT J. E., 1992. Homopteran honeydew sugar composition is determined by both the insect and plant species. *Comparative Biochemistry Physiology*, 101 B, 1/2, 23-27.
- HEQUET E., 1988. Egrenage, stage aux USA. Document interne CIRAD, 60 p.
- HEQUET E., FRYDRYCH R., 1990. Methodology of use of the IRCT-RF13 thermodetector. *Proceeding of International Committee on Cotton Testing Methods*. ITMF, appendix 11, 1-4.
- HEQUET E., FRYDRYCH R., 1992. Some exemples for the use of the sticky cotton thermodetector. *Proceeding of Beltwide Cotton Conferences*, 1145-1147.
- HEQUET E., FRYDRYCH R., 1992. Sticky cotton from plant to yarn. *Proceedings, International Committee on Cotton Testing Methods of ITMF*, Brème, Allemagne, appendix 46, 3-19.
- HEQUET E., FRYDRYCH R., 1993. Neutralisation du collage de la fibre de coton. Document interne CIRAD et Ministère de l'Industrie, 85 p.
- HEQUET E., 1993. Rapport de mission CAMEROUN. Document interne CIRAD, 24 p.
- HEQUET E., FRYDRYCH R., WATSON M., 1997. The use of high speed stickiness detector on a large range of cotton coming from different countries. *University of Huddersfield, World Textile congress on Natural and natural-Polymer Fibres*, July 97, 200-211.
- HEQUET E. and WYATT B., 1999. Evidences on the origines of sugars causing stickiness in cotton. *Proceedings, Beltwide Cotton Conference*, Orlando, FL, USA, 698-701.
- HEQUET E., 1999. Application of the AFIS Multidata. *Beltwide Cotton Conferences*, January 3-7, Orlando, FL (USA), National Cotton Council of America. Memphis, TN (USA), pp. 666-670.
- HEUER Bruria and PLAUT Z., 1985. A new approach to reduce sugar content of cotton fibers and its consequence for fiber stickiness. *Textile Research Journal*, may, 263-266.
- HILLOCKS R. J., BRETELL J. H., 1993. The association between honeydew and growth of *Cladosporium herbarum* and other fungi on cotton lint. *Tropic Sciences*, 33, 121-129.
- HOELSCHER K. and ETHRIDGE D., 1998. How much does the market fear stickiness ? Evidence from the 1996 crop year. *Proceeding of Beltwide Cotton Conferences*, San Diego, CA, USA, 331-334.
- HUNTER L., 1994. HVI working group. *Proceedings, International Committee on Cotton Testing Methods of ITMF*, Brème, Allemagne, appendix 7, 1-14.
- ICAC, 1990. Gestion de la résistance aux pyrèthréinoïdes : théorie, recherches et pratique. *The ICAC recorder*, technical information section, 8, 3, 16-24.
- ICAC, 1994. Production et recherche cotonnière au Soudan. *The ICAC recorder*, technical information section, 14-17.
- ICAC, 1996. Cotton review of the world situation 95-96, may-june, 16 p.
- ICAC, 1999. Coton : statistiques mondiales. *Bulletin du Comité Consultatif International du Coton*, Octobre, 111 pages.
- ICTRD, 1993. Sticky cotton examined in Texas, Oklaoma region. *Textile Topics of International center for textile research and development*, 21, 9-12, 4 p.

- ISHAQ A.R., 1984. Structure and mechanical properties of some native and modified cotton fibres. University of Strathclyde, Glasgow, Angleterre, thèse, 297 p.
- ITMF, 1989 to 1999. Cotton contamination foreign matter and stickiness. Cotton Contamination Survey, édité par ITMF, Zurich, Suisse, 55 p.
- JACKSON J. E., BURHAN H. O., HASSAN H. M., 1973. Effects of season, sowing date, nitrogenous fertilizer and insecticide spraying on the incidence of insect pests on cotton in the Sudan Gezira. *Journal of Agriculture Sciences, Camb.*, 81, 491-505.
- JENNINGS Edwin J., 1953. Another look at honeydew. Note interne ACCO Fiber and Spinning Laboratory, Anderson, Clayton and Compagny., Houston, Texas, Etats-Unis, 12 p.
- JOHNSON L. , KOTZ S. and KEMP A. W. , "Univariate Discrete Distributions", 2nd ed., John Wiley, NY, 1992, pp.199-210.
- KHALIFA H., EL-KHIDIR E., 1964. Biological study on *Trialeurodes lubia* and *Bemisia tabaci*. *Bulletin Société Entomologique d' Egypte*, 48, 115-129.
- KHALIFA H., GAMEEL O.I., 1982. Control of stickiness through breeding cultivars resistant to whitefly (*Bemisia tabaci* Genn) infestation. Improvement of oil seed and industrial crops by induced mutations. IAEA, 181-186.
- KRIFA M., 1997. Contribution à l'étude de l'impact des fragments de coque de graine sur la qualité du fil de coton (*G. hirsutum*). D.E.A. Génie des processus et des matériaux textiles et paratextiles, Université de Haute Alsace. 69 pp.
- KRIFA M., GOURLOT J.-P., FRYDRYCH R., 1998, Identification et comptage des fragments de coque sur voile de carte et sur fil par analyse d'image, Journées Coton du Cirad CA, 20-24 juillet 1998, pp 73-81.
- KRIFA M., BACHELIER B., FRYDRYCH R., HOFS J.-L., 1998. Trashcam : counting seed coat fragments for cotton breeding. Réunion du comité technique ICAC. 57ème réunion plénière de l'ICAC, " ICAC Technical Seminar, October 15 1998, Santa Cruz (Bolivia)".
- KRIFA M., VYDELINGUM V., GOURLOT J.-P., FRYDRYCH R., 2000, Seed-Coat Fragment effect on carded cotton yarn evenness, Beltwide Cotton Conferences, January 4-8, San Antonio, TX (USA), National Cotton Council of America. Memphis, TN (USA), pp.1538-1541.
- KRIFA M., BACHELIER B., FRYDRYCH R., GOURLOT J.-P., GINER M., 2001, Relationship between seed coat fragment content and yarn strength depending on the range of fiber quality, Beltwide Cotton Conferences, Anaheim (CA), 8-13 janvier 2001.
- LADYMINA L. P., 1990. Problem of cotton's stickiness in the USSR. In : Cotton production research from a farming perspective, with special emphasis on stickiness. Paper presented at a Technical Seminar at the 49th Plenary meeting of the ICAC, Montpellier, France, 42-43.
- LECLANT F., DEGUINE J.-P., 1994. Aphids (Hemiptera: Aphididae). Cab International, Insects pests of cotton; édité par MATTHEWS G.A. and TUNSTAL J.P., 285-323.
- MARQUIE C., BOURELY J., BONVALET A., 1983. Etude chimique d'un dépôt collant sur turbines "open-end". *Coton et Fibres Tropicales*, 38, 4, 323-326.
- MARQUIE, 1994. La graine de cotonnier dans l'alimentation traditionnelle au Benin. Document interne CIRAD, 42 p.
- MASSAT J., 1988. Note sur la relation entre le test minicarde et la marche des machines textiles. Document interne CIRAD, 14 p.
- MATTHEWS G. A., 1989. Cotton insect pests and their management. Longman Scientific and Technical Ed., Harlow, Essex, UK, 199 pages.
- MENOZZI P., 1996. L'aleurode *Bemisia tabaci* Gennadius sur le continent Américain et Caraïbes. Série: Les déprédateurs du Cotonnier en Afrique Tropicale et dans le reste du monde. Document interne CIRAD, 50 p.
- MERON M., TZIPRIS Y., PORATH A. B., 1992. Identification of honeydew aggregates on cotton lint by direct inspection. Proceedings, International Committee on Cotton Testing Methods of ITMF, Brème, Allemagne, appendix 50, 1-13.

- MICHEL B., 1989. Une nouvelle perspective pour la maîtrise des déprédateurs du cotonnier au Paraguay: les seuils d'intervention. *Coton et Fibres Tropicales*, 44, 2, 127-140.
- MILLER T. A., 1985. International status of pyrethroid resistance. *Proceedings, Beltwide Cotton Conference, San Antonio, Texas, Etats-unis*, 123-125.
- MINKENBERG O., SIMMONS G. S., MALLOY R., KALTENBACH J, LEONARD C., 1994. Biological control of whiteflies on cotton : a reality check. *Proceedings, Beltwide Cotton Conference, San Diego, Californie, Etats-Unis*, 887-890.
- MORTON W. E., HEARLE J. W. S., 1962. Physical properties of textile fibres. *Equilibrium absorption of water. Textile Institute and Butterworth*, 159-177.
- MOR U., 1994. A new system for fiber quality mass testing : an on line and real time system (LINTRON-S). *Proceedings, International Committee on Cotton Testing Methods of ITMF, Brème, Allemagne*, appendix 28, 1
- MOR U., 1998. Further development of the fibre contamination tester. *International Cotton Conference, Bremen, Germany*, 217-224.
- MOUND L. A., 1962. Extra-floral nectaries of cotton and their secretions. *The Empire Cotton Growing Review*, 34, 4, 254-261.
- MOUND L. A., 1965. Effect of whitefly (*Bemisia tabaci*) on cotton in the Sudan Gezira. *The Empire Cotton Growing Review*, 290-294.
- MUMFORD J. D., NORTON G. A., 1994. Pest management systems. *Cab International*, 28, 559-576.
- PARRY G., 1982. Le cotonnier et ses produits. *Techniques Agricoles et Productions Tropicales*, 494p.
- PELES S., 1992. The Israeli Classing Institute method for cotton stickiness evaluation. *Proceedings, International Committee on Cotton Testing Methods of ITMF, Brème, Allemagne*, 53-54.
- PERKINS H. H., Jr., 1971. Some observations on sticky cottons. *Textile Industries*, march 1971, 49-64.
- PERKINS H. H., Jr, 1971. Rapid screening test for sugar content of cotton. *Textile Bulletin*, august 1971.
- PERKINS H. H., Jr., 1975. Oil contamination of cotton in harvesting. *Issue of the Cotton Gin and Oil mill Press*, 2 p.
- PERKINS H. H., Jr., ROBERTS C. W., BASSETT D. M., 1976. Characterization of non-cellulosic constituents of variety test cottons. *Proceedings, Beltwide Cotton Conferences, Etats-Unis*, 91-93.
- PERKINS H. H., Jr., BRAGG Charles K., 1977. Effects of oil contamination on cotton quality : methods of analysis and characterization of contaminants. *Textile Research Journal*, 47, 4, 271-277.
- PERKINS H. H., Jr., BARGERON J. D., 1980. Nep forming on a cotton card in relation to fiber maturity and cotton preparation procedures - honeydew - additives as a means to reduce air-borne dust. *Proceedings of the International Committee on Cotton Testing Methods of ITMF, Brème, Allemagne*, 3 p.
- PERKINS H. H., Jr., 1983. Identification and processing of honeydew-contaminated cottons. *Textile Research Journal*, august, 508-512.
- PERKINS H. H., Jr., 1983. Effects of whitefly contamination on lint quality of US cottons. *Proceedings, Beltwide Cotton Conference, Etats-Unis*, 102-103.
- PERKINS H. H., Jr., 1991. Cotton Stickiness. A major problem in modern textile processing. *Proceedings, Beltwide Cotton Conference, San-Antonio, Texas, Etats-Unis*, 2, 523-524.
- PERKINS H. H., Jr., HUGHS S. E., LALOR William , 1992. Preliminary results of gin additive research. *The Cotton gin and oil mill press*, june 27, 6-9.
- PERKINS H. H., Jr, 1993. A survey of sugar and sticky cotton test methods. *Proceedings, Beltwide Cotton Conference, New Orleans, Louisiane, Etats-Unis*, 3, 1136-1141.
- PERKINS H. H., Jr., BRUSHWOOD D. E., 1994. Cotton stickiness determined by the thermodetector method. *Proceedings, Beltwide cotton Conference, San Diego, Californie, Etats-Unis*, 3, 1412-1413.
- PERKINS H. H., Jr., 1994. The thermodetector method for assessing cotton stickiness. *Proceedings, International Committee on Cotton Testings Methods of ITMF, Brème, Allemagne*, appendix 30, 2 p.

- PERKINS H. H., Jr, Brushwood D. E., 1995. Interlaboratory evaluation of the thermodetector cotton stickiness test method. Proceedings, Beltwide Cotton Conference, San Antonio, Texas, Etats-Unis, 2, 1189-1191.
- PLATT, 1977. Shirley miniature spinning plant. Document technique Platt, Angleterre, 20 p.
- PRICE J. B., 1983. Research on fiber / yarn relationship. Textile Topics, 11, 10.
- RAJAK R. L., DIWAKAR M. C., 1987. Resurgence of cotton whitefly in India and its integrated management. Plant Prot. Bull., 3, 13-14.
- RAMEY H. H. Jr., LAWSON R., and WORLEY S. Jr., 1977. Relationship of cotton fiber properties to yarn tenacity. Textile Research Journal, 47 (10): 685-691.
- RAYMOND G., MARQUIE C., 1995. La graine de cotonnier et ses produits. OCL, 2, 6, 422-424.
- RENOU A., CHENET T., 1989. Efficacité de matières actives insecticides contre les stades fixés de l'aleurode *Bemisia tabaci* (Genn.) en culture cotonnière au Nord Cameroun. Coton et Fibres Tropicales, 44, 1, 21-33.
- RENOU A., DEGUINE J. P., 1992. Ravageurs et protection de la culture cotonnière au Cameroun. Coton et Fibres Tropicales, série Documents, Etudes et Synthèses, n°13, .
- RENNER M., 1986. Contribution à l'étude théorique et expérimentale du processus d'obtention des textiles linéaires. Université de Haute Alsace, Mulhouse, France, thèse 261 p.
- ROBERTS C. W., KOENIG H. S., MERRILL R. G., CHEUNG P. S. R., PERKINS H. H., 1976. Implications of monosaccharides in sticky cotton processing. Textile Research Journal, may, 374-380.
- ROBERTS C. W., CHEUNG P. S. R., PERKINS H. H., Jr., 1978. Implications of monosaccharides in sticky cotton processing : part II : effects of growing conditions on fiber contaminants. Textile Research Journal, 91-96.
- ROBERT B., 1992. Cotton insect losses 1991. Proceedings, Beltwide Cotton Conference, Nashville, Tennessee, Etats-Unis, 621-625.
- ROGERS C. E., 1985. Extrafloral nectar : entomological implications. Fall, 15-21.
- SALAMA S. S., RIZH A. F., SHARABY A., 1984. Chemical stimuli in flowers and leaves of cotton that affect behaviour in the cotton moth *Spodoptera littoralis*. Entomologia generalis, 10, 27-34.
- SAPORTA G., 1990. Probabilités, analyse des données et statistiques. Edité par Technip, 493 p.
- SCANERA, 1992. Brevet : dispositif de détection de défauts de matériaux fibreux, FR 9209258.
- SCHENEK A., 1996. Progress report. International Committee on Cotton Testing Methods of ITMF, Brème, Allemagne, 8 p.
- SGICF, 1991. Collage des cotons bruts. Document du Syndicat Général de l'Industrie Cotonnière Française, Paris, France, 4 p .
- SHIGEAKI IZAWA, 1992. The seriousness of cotton contamination problem as viewed from a spinner's position. Papers presented at a Technical Seminar at the 51th Plenary meeting of the ICAC, Liverpool, Angleterre, 10 p.
- SISMAN S., SCHENEK A., 1984. New method for testing the stickiness of cotton. Melliand Textilberichte, International Textile reports, 3 p.
- STEWART J.,Mc.D., 1975. Fiber initiation on the cotton ovule (*Gossypium hirsutum*). American Journal of Botany, 62 (7), 723-730.
- SYLVIE P., PAPIEROCK B., 1991. Les ennemis naturels d'insectes du cotonnier au Tchad : premières données sur les champignons de l'ordre des Entomophthorales. Coton et Fibres Tropicales, 46, 293-303.
- TAMIME O., 1996. Etude de la précision et de la répétabilité des mesures de collage du coton sur le thermodétecteur SCT. Ecole Nationale Supérieure Industrie Textile de Mulhouse, France, DEA, 50 p.
- TAMIME O., GOZE E., FRYDRYCH R., GOURLOT J-P., DREAN J.-Y., 1999, Classement des balles de coton selon leur potentiel de collage mesuré par le High Speed Stickiness Detector (H2SD), Doctoriales de l'Université de Haute Alsace in Mulhouse (France), Mai 1999.
- TAMIME O., 2000. Etude de la filatilité des cotons collants et de la classification des balles selon leur potentiel de collage mesuré par le H2SD. Thèse de doctorat, 26/06/2000, 233 pages.

- TARCZYNSKI M. C., BYRNE D. N., MILLER W. B., 1991. High performance liquid chromatography analysis of carbohydrates of cotton-phloem sap and of honeydew produced by *Bemisia tabaci* feeding on cotton. Plant Physiological, 92, 753-756.
- TAYLOR R. A., ROGERS C. D., DRUYN C. W., 1988. Evaluation of near infrared reflectance to predict honeydew stickiness of cotton. Proceedings, International Committee on Cotton Testings Methods of ITMF, Brème, Allemagne, appendix 11, 15 p.
- TOMASSONE R., 1992. Comment interpréter les résultats d'une régression linéaire. STAT-ITCF, Institut Technique des Céréales et des Fourrages, 55 p.
- VAISSAYRE M., 1983. L'association pyrèthroïde-organophosphoré, pour une protection des cultures cotonnières : choix des proportions les plus efficaces. Coton et Fibres Tropicales, 38,3, 269-273.
- VAISSAYRE M., 1985. Development of pyrethroid organophosphate associations for cotton pest control in french speaking africa. Proceedings, Beltwide Cotton Conference, San Antonio, Texas, Etats-Unis, 127-128.
- VAUTIER M., 1971. Dosage des sucres responsables du collage de certains cotons en filature par chromatographie sur papier. Bulletin ITF, 25, 156, 747-755.
- VERSCHRAEGE L., FRANSEN T., 1988. Measurement of cotton seed fragments and their origin in cotton fiber after ginning. Coton et Fibres Tropicales, 43, 4, 299-306.
- WAEBER R., DEMUTH R., KNABENHANS F. and BACHMANN O., 1990. Method of reducing the stickiness of cotton fibers. US patent n°4.969.234.
- WATSON M., 1994. Comparisons between cotton sugar content, stickiness, and other fiber properties. Proceedings, International Committee on Cotton Testings Methods of ITMF, Brème, Allemagne, appendix 26, 1-3.
- WATSON M., 1994. Activities of JSA, SCAT, SCTF and other groups. Proceeding International Cotton Conferences, Bremen, Germany, appendix 5, 93-94.
- Watson M., 1998. Activities of JSA, SCAT SCTF and other groups. Proceeding International Cotton Conferences, Brème, Appendix S-5, pp. 93-94.
- WYATT B. G., 1976. Sticky cotton. Textile Industries, 144-165.
- YAO S. C., 1990. A study on the effect of raw cotton stickiness distribution on the spinnability. China Textile Institute, Taiwan, 8 p.

Abbreviations and acronyms

ICAC	-	International Cotton Advisory Committee, Washington (USA)
CFC	-	Common Fund for Commodities (Netherlands)
SCC	-	Sudan Cotton Company (Sudan)
ARC	-	Agricultural Research Corporation (Sudan)
ITF	-	Institut Textile de France (France) newly renamed as IFTH
CI		Cotton Incorporated, Cary, NC (USA)
ITMF	-	International Textile Manufacturers Federation (Switzerland)
CIRAD-CA	-	Centre de Coopération Internationale en Recherche Agronomique pour le Développement - Département des Cultures Annuelles (France)
USDA	-	United States Department of Agriculture

LIST OF LABORATORY EQUIPMENT

FMT	: Fineness Maturity Tester
H2SD	: High Speed Stickiness Detector
HPLC	: High Performance Liquid Chromatography
HVI	: High Volume Instrument
SCT	: Sticky Cotton Thermodetector
UT3	: Uster Tester 3
Tensorapid	: Uster Dynamometer

DISCLAIMER

Mentions of equipment brands or models in this document do not constitute any form of recommendation for such equipment.

LIST OF VARIABLES

SCT: number of SCT sticky points

H2SD: number of H2SD sticky points

Small: number of sticky points between 1.7 and 9 mm²

Medium: number of sticky points between 9 and 18 mm²

Large: number of sticky points larger than 18 mm²

TMH2SD: average size of the H2SD sticky points

TTH2SD: total size of the H2SD sticky points

I: inositol

T: trehalose

G: glucose

F: fructose

W: trehalulose

S: saccharose or sucrose

M: melezitose

Stotal: percentage of total sugars

C-CT100km: total breaks per 100 km of card sliver

C- Efficiency: card efficiency (efficiency = yield)

E1-CT100km: total breaks per 100 km of drawing frame sliver (1° draft)

E1-Efficiency: drawing frame efficiency (1° draft)

E2-CT100km: total breaks per 100 km of drawing frame sliver (2°draft)

E2-Efficiency: efficiency of the drawing frame (2°draft)

B-CT100km: total breaks per 100 km on the flyer

B-Efficiency: efficiency of the flyer

CAF-TC1000BH: breakage per 1,000 spindles/hour on the ring spinning frame

OE-Efficiency: efficiency of the Open-end machine

OE-Y-P240BH: number of piecing per hour for 240 open end positions

OE-LR240BH: number of interventions per hour for 240 open end positions.

C-CV%: CV% mass variation on card sliver

E1-CV%: CV% mass variation on 1° draft drawing frame

E2-CV%: CV% mass variation on 2° draft drawing frame

B-CV%: CV% mass variation on flyer yarn

CAF-UT3-CV%: CV% mass variation on ring spun yarn

CAF-UT3-50%: No. of thin places per km of ring spun yarn

CAF-UT3+50%: No. of thick places per km of ring spun yarn

CAF-UT3-Neps: No. of neps per km of ring spun yarn

CAF-Hairiness: Hairiness of the ring spun yarn

CAF-Elongation: Elongation (%) of the ring spun yarn

CAF-Strength: Strength (cN/tex) of the ring spun yarn

CAF-Work: Work to break (N.cm) of RS yarn

OE-UT3-CV%: CV% mass variation of the OE yarn

OE-UT3-50%: No. of thin places per km of OE yarn

OE-UT3+50%: No. of thick places per km of OE yarn

OE-UT3-Neps: No. of neps per km of OE yarn

OE-Hairiness: Hairiness of OE yarn

OE-Elongation : Elongation (%) of OE yarn

OE-Strength: Strength (cN/tex) of OE yarn

OE-Work: Work to break (N.cm) of OE yarn

χ^2 : Variable of the Chi² distribution

α : Confidence level (Type I error)

+B: Yellowness

H: Fiber linear fineness (mtex)

HS: Standard fineness (mtex)

IM: Micronaire

k: Shape factor for the binomial negative distribution

m: Parameter for the binomial negative law (mean)

ML: Mean length (mm)

MR: Maturity ratio

PM%: Percent of mature fibers (%)

Rd%: Reflectance (%)

RL: Litigation risk

SCE: Sum of squares of the deviates

UHML: Upper Half Mean Length (mm)

UI%: Uniformity index (%)

